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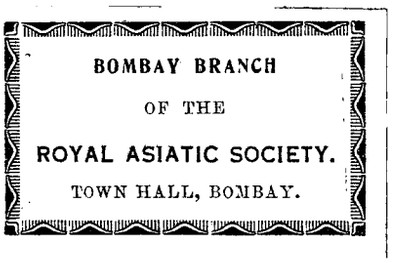

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THE METEOROLOGY

OF THE

BOMBAY PRESIDENCY,

BY

CHARLES CHAMBERS, F.R.S.,

SUPERINTENDENT OF THE COLABA OBSERVATORY, BOMBAY.

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THE METEOROLOGY OF THE BOMBAY PRESIDENCY.

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THE METEOROLOGY OF THE BOMBAY PRESIDENCY.

A FEW words as to what are regarded as judicious objects of meteorological research are perhaps necessary in justification of the moderate and unpretending aims of the greater part of the discussions which are embodied in this paper. It falls to the lot of but a few devotees of any branch of science, in a single generation, to alight upon one of the grand theoretical ideas which thenceforward becomes the firm and generally accepted basis of further investigation; and in observational as distinguished from experimental science, there is good reason why a student, who considers the results of the expenditure in this field of enormous mental labour by his predecessors, should aim to contribute to the stock of human knowledge in some humbler capacity than that of a discoverer of physical principles. For whilst the experimental inquirer can vary the conditions under which a phenomenon presents itself, and—in the words of Dr. Balfour Stewart—so cross-question the facts, that a single explanation alone remains possible, the observer must be content to take natural phenomena as they come before him, having no power to vary the complication of circumstances which surround them, but relying upon such variations as differences of time and place afford, to give him a possible clue to efficient physical causes. The faculty which enables the enthusiastic inquirer to imagine such physical conditions and actions as would, consistently with established facts and laws, produce effects corresponding in kind to the observed facts, and to calculate or estimate their adequacy to produce effects of the magnitude of those observed, finds wide scope for exercise in the consideration of observational phenomena; but [illegible]n speculations of this nature that experience of the past would counsel the student [illegible]rology to spend his energies mainly. It is rather to the accumulation of well [illegible]henomenal laws, as educed from observations at numerous stations widely [illegible] the world, and taken under all varieties of conditions as to times and seasons, [illegible]ook, as means to safe inductions, leading ultimately to physical causes that [illegible]all the observed phenomena.

[illegible]ustration we may mention Kepler's laws of the motions of the planets round [illegible] consideration of which led Newton to the law of universal gravitation, as [illegible] phenomenal laws which in a comparatively simple case—three general conditions [illegible]g to be satisfied—led to a sound induction. But in meteorology the phenomenal [illegible] are generalizations regarding complex phenomena, and are necessarily of much [illegible]te and exact character than those of Kepler; and the problem which the higher [illegible]s have here to solve being one whose complexity is of a very high degree, it is not [illegible]g that, in general, physical theories in meteorology have yet to be accepted as [illegible] only.

3. And whilst in meteorology the right may be conceded to the amateur observer to engage himself in that branch of the study in which he finds greatest interest, it may by no means be allowed to the professional observer, who is a public servant, and whose time and powers must therefore be held by him as in trust, to occupy himself to any considerable extent upon the direct pursuit of general principles, when the probabilities of the ultimate attainment of useful generalizations lie in the less ambitious path of formulating numberless isolated facts.

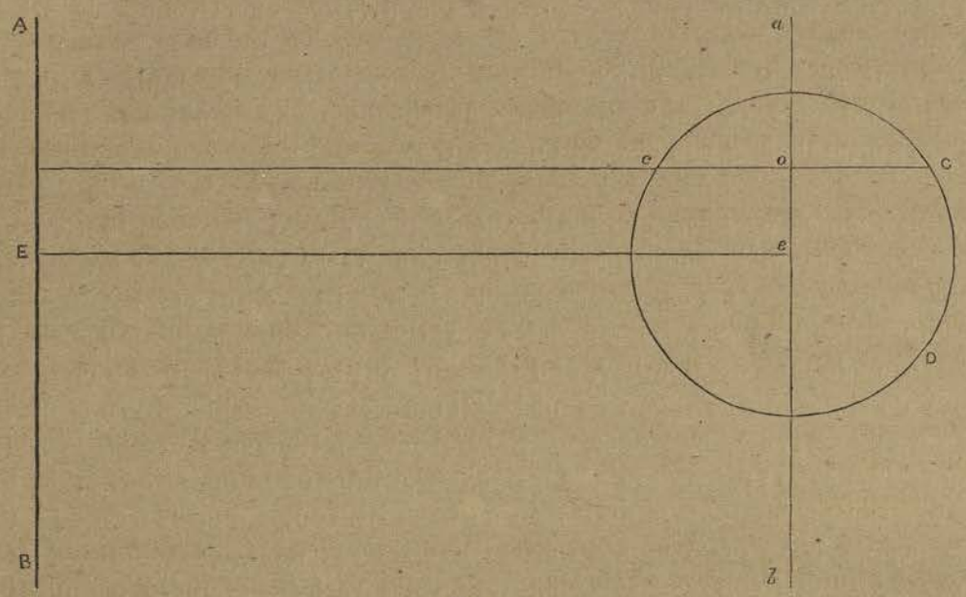
4. Amongst modern contributions to our knowledge of the observational sciences, the voluminous discussions by General Sir Edward Sabine of the observations of the British colonial observatories hold a very prominent place, and they are almost entirely directed to the establishment of phenomenal laws. The example of this high authority would therefore seem to discountenance the habit of theorizing upon the meagre collection of phenomenal laws that an individual inquirer is able to bring together by his own efforts; and leads us to conclude that co-operation by observers in all parts of the world, towards the amassing of a sufficient body of phenomenal laws to admit of secure higher generalizations, is a much more judicious function of individual inquirers, who deal directly with the crude facts observed, than the more fascinating and ultimately more important search after physical theories.

With these preliminary remarks we may proceed to indicate the line of inquiry that we shall adopt.

5. It is a matter of universal experience that the climatic conditions of the earth's surface vary with change of place at the same time, and vary also with change of time at the same place. In other words, the winds, rains, temperature, moisture, &c., experienced at the same time at one place on the earth's surface are different from those experienced at another place, and those experienced at the same place at a given hour of a given day in a given year are different from those experienced when either the hour, the day, or the year are changed. Apart from the consideration of the physical causes of these differences, the knowledge of which is the ultimate object to be attained, meteorology presents to the stud[ent] two great problems which—the independent variables being respectively space an[d] are in nature interwoven throughout in great complexity: these are, first, at any gi[ven] to determine the relations which subsist between the *absolute* values of the [m] elements (temperature, &c.), both amongst themselves and when regarded [in] we change our position in latitude, longitude, and height, and as the physica[l] the earth's surface changes; and, secondly, at any given place to determine which subsist between the *absolute* values of the meteorological elements, [in] themselves and regarded individually, as we change the time, that is, as we cha[nge] season, year, &c.

6. It will presently be seen that, although these problems correctly in[dicate] immediate objects of meteorological inquiry, it would be inconvenient and undes[irable] regards the first, hitherto even impracticable—to attack them directly. The cha[nges] follow at any place upon change of time simply, are known to be in the main per[iodic] character, the principal periods being a day and a year. Now it is a property of a

periodical phenomenon that, whatever part of the period we regard, it resumes the same condition after the lapse of one or any number of exact full periods, and thus it produces no progressive increase or decrease of the absolute value of the element concerned at any part of the period; neither will it therefore produce any such progressive increase or decrease of the average absolute value of the element for the whole period. To illustrate this, let us consider the distance of the point C (*see* fig. *a*) from the line A B as C travels uniformly



(Fig. *a*.)

round the circle C D: whatever point of the circle C may be regarded as starting from, it will, by the time it has made a full circuit, be at the same point again, and therefore at the same distance from A B; and if we look upon the actual distance of C, at any moment, as made up of two artificial distances, first of E *e*, the average distance from A B, of all the points which may be taken along the circle C D, and, second, of C O the distance considered an excess or a defect according as C is to the right or left of O, then esses and defects C O, taken with positive and negative algebraical signs, excesses and defects being taken for positions of C equidistant along the this would be approximately true if any other figure than a circle were providing E *e* were the exact average of the distances of a considerable ssive positions taken up by C, and these positions were taken up after equal The line E *e* we call the *normal* distance of C from A B, and the succession negative values of C O, whose sum is *zero*, we call the *variation* of the distance , in C's period: similarly we call the average value of any phenomenon, taken alues at equidistant times in its period, its *normal*, and the series of positive numbers, which represent the excesses and defects of the actual values of the above its average, we call its *variation* in the period in question, and any one cesses or defects we call the *inequality* of the phenomenon, with respect to the e particular moment.

7. Two great advantages are gained by the artificial separation, in the manner indicated, of a phenomenon into normal and periodical components: first, that the components, when viewed separately, are of simpler character, and therefore are more readily comprehended than the original complex phenomenon; and, secondly, that, as the physical cause of a variable component must itself be subject to a variation having the same period, it limits the search for efficient causes to such as are subject to that period, and thus directs inquiry into fruitful channels. On the other hand the normal component must be regarded as a measure of the *average* effectiveness of all the causes that are in operation.

The analyzation indicated will be best understood by an example of its application, which may be obtained in the course of our consideration later of the observations of barometric pressure taken at the Colába Observatory.

8. The plan which we have adopted for this paper is, in Part I. to give a very brief sketch of the history and character of the Colába Observatory, and an account of the records which are available and fit for discussion, and to examine and comment upon the general results which have been educed from the observations, both as to the typical character of the climate of Bombay, and the periodical variations to which it is subject; in Part II. to do the same as regards four small observatories, which have been maintained for the last seventeen years, or longer, at the military stations of Kurrachee, Deesa, Poona, and Belgaum; in Part III. to state the principal results of observations taken at the civil and military hospitals, and of rainfall returns from Revenue officers; and in Part IV. to combine the whole body of results so as to exhibit some principal points in the general character of the climate of the Presidency, and its variations under change of physical conditions, and with change of season. This division of the subject is convenient, both because the range of subjects and frequency of observations follows the order adopted, and because the conditions under which the observations were taken were of a kind to secure accuracy and trustworthiness also in the same order; and in both respects a high order of efficiency and value is followed by gradations which reach the lower limit of all but absolute worthlessness.

PART I.

THE COLÁBA OBSERVATORY AND ITS OBSERVATIO

9. *Astronomical Observatory and instruments.*—The main building
Observatory was designed for an astronomical observatory, and was erec
the instruments with which it was furnished were nearly all returned to E
purpose of establishing an astronomical observatory fell through, The o
instruments with which the meteorological observations of a later period are
the transit instrument, which, after some modifications, was erected in 1840,
into regular use in September 1841, and the sidereal clock; the latter, by Thwait
has a gridiron pendulum, and is an excellent time-keeper; the former, by W. an
is a 5-foot telescope with 3-foot axis and $3\frac{1}{2}$-inch object glass. These instrument
used for the determination of local time, primarily for communication to the

Bombay harbour, and secondarily for communication to the Magnetical and Meteorological Observatory; and as the former purpose requires greater nicety and regularity than the latter, ample provision has always been made that correct time should be available for meteorological purposes. The standard time-keeper of the Magnetical and Meteorological Observatory was a ship's chronometer, which, since 1852, was frequently compared with the time of the Astronomical Observatory, but before that year the chronometer errors are recorded only occasionally.

10. *Geographical position of Observatory.*—The adopted latitude and longitude of the Colába Observatory are 18° 53′ 45″ north, and 72° 48′ 12″ east respectively; both of which have been furnished by the Great Trigonometrical Survey, the latter being derived from the Nautical Almanac value of the longitude of Madras (80° 14′ 19″), and the difference between the longitudes of the two observatories given by triangulation (7° 26′ 7″).

11. *Local situation.*—The observatory is situated at the extremity of a narrow strip of land extending two miles to the south-westward of the Fort of Bombay and separating the harbour and Back Bay. Trap rock, which is very abundant in the ground near and on the surrounding sea-beach, crops up at many places through the red sandy soil which covers the greater part of the observatory enclosure. During the rainy months of the year the soil is overgrown with grass, which, however, is quickly burned up when the dry season comes round. The nearest elevated ground is Malabar Hill, which lies on the opposite side of Back Bay, at a distance of four miles, but that which subtends the largest vertical angle, as seen from the Magnetical and Meteorological Observatory, is the southern hill of the Island of Karanja, at a distance of about eight miles. The altitude of the highest point of the latter is less than 1° 7′. An idea of the aspect and nature of the surrounding country, and of the exposure of the thermometer shed and anemograph, will be best obtained by an inspection of the accompanying photographs, which form a series of panoramic views all round the compass, together with some near views of the buildings and instruments.

A plan of the grounds and buildings of the observatory, and an index showing the names and uses of the several buildings, is given in Plate A. Trees of large growth are scattered about the grounds, and occupy the places marked with black dots (●) on the plan, whilst a few smaller trees stand on the places marked with crosses (×), the remaining space being for the most part quite open.

12. *Description of the plan and buildings.*—The buildings marked A and E are the Astronomical and Magnetical Observatories respectively; the former is raised on a mound, the top of which is 10 feet higher than the basement of E, and from it there is a gradual decline on all sides reaching at the Tide Gauge House O, a maximum of about 30 feet. The block of buildings of which A forms a part has thick masonry walls, and the four arms of the cross consist of ground-floor rooms only, but with vaults underneath, whilst upon the central square C is raised a cylindrical tower, surmounted by a wooden dome [illegible]tends to a height of 50 feet above the ground. Since June 1867, Robinson's [illegible]r has occupied the top of the dome, having a platform 12 feet in diameter

at its foot, partly to render the external parts of the machine accessible, and partly to prevent the formation, near the instrument, of irregular currents of wind glancing from the dome. On the eastern side of the room A are mounted the large transit instrument and the standard sidereal clock. The pillars, formed of large blocks of stone, upon which these instruments rest, and whose foundations are independent of those of the building, are marked on the plan *i*, *i*, and *m*; that of the clock adjoins the eastern transit pillar. A small room B, adjoining the block A, D, D, D, to the north of the transit pillars, contains a collimator mark (for use with the transit instrument) mounted rigidly on a masonry pillar *n*. The remaining parts D, D, D, of the block are allotted as a dwelling-house to the superintendent. The standard barometer is mounted in the Magnetic Observatory E, and in this room the observers sit, and the current magnetical and meteorological registers are kept. Adjoining E at its north-east corner is a square tower F, 46 feet high, called the Electrometer Tower, on the roof of which has been placed, since the beginning of the monsoon of 1866, Osler's rain gauge. The room N was used in 1865 as a store-room for old instruments and manuscripts, but in the year 1868 all the manuscript records and printed volumes of observations were for greater security removed from that room, which is infested with white ants, to the room M, where they are now regularly examined and kept in order. The large room M, to the westward of the Astronomical Observatory, was formerly used as store-room and office for the Indian Naval Draughtsman's Department. Since the year 1866 this room has been used, instead of the large Magnetical Observatory, as a computing room, thus placing the computers more continuously under the supervision of the superintendent. In 1869 the western end of the room was partitioned off and fitted up as a photographic operating room.

All the buildings, except the small Magnetical Observatory, and the hamal's and a portion of the assistants' quarters, have substantial masonry or brick walls, and are preserved generally in a state of good repair. The roofs are mostly of red tiles, but that of the Astronomical Observatory is of wooden planks, covered with sheet copper, overlaid with mortar and asphalt. There is a planked roof to the electrometer tower in the shape of a low square pyramid, covered with felt and canvas, and it has over all a coat of white paint. The present thermometer shed H, which was brought into use in 1851, is situated 30 feet to the south-eastward of the large Magnetical Observatory.

13. *Origin of Magnetical and Meteorological Observatory.*—No meteorological observations taken at the Colába Observatory are on record till the year 1841, when, on the recommendation of the Royal Society, the observatory became associated, in the prosecution of magnetical and meteorological research, with the British colonial observatories of Toronto, St. Helena, the Cape of Good Hope, and Hobarton, and with the Indian Government observatories of Madras, Singapore, and Simla. From this year its active life must be reckoned. Its first director was Mr. Arthur B. Orlebar, the professor of astronomy and mathematics in the Elphinstone College, and to his judgment and ability—displayed in starting the undertaking, under very adverse circumstances, on a thoroughly sound system—it is mainly owing that, through long after years of less able direction, the observatory nevertheless produced magnetic records that are now found to be [redacted] value; whilst in meteorology the results of the observations themselves afford

evidence that, during the period (1844, and 1847 to 1872) to which they refer, judgment and care were throughout used in the conduct of the observatory.

14. *Meteorological records used for the present discussion.*—The regular registration of magnetical and meteorological observations commenced in November 1841, and, with few interruptions, the observations were taken hourly (generally omitting Sundays) until the end of April 1842; from May to August 1842 the night observations were omitted, but the complete hourly observations were resumed on 1st September 1842, and continued, with the possible exception of January to March 1845, till the end of 1846; from January to May 1847 the observations appear to have been taken at the even hours *only*, of Göttingen mean time, and thenceforward, till the end of the year 1872, again hourly. The original manuscript registers, of date prior to 1st June 1847, have all disappeared; and there remain at the observatory, of meteorological records in manuscript, none whatever till the 1st September 1842, nor from January to March 1845; two bound volumes, which appear to contain copies only, of two-hourly registers from September 1842 to December 1843; monthly abstracts of hourly readings of individual instruments, from January to December 1844, with daily and hourly sums and means calculated, and from April 1845 to December 1846 unreduced; similar monthly abstracts of two-hourly readings from January to May 1847, with sums and means calculated; and from 1st June 1847, to the end of 1872, both original registers and abstracts complete and reduced. On the 31st December 1872, a set of photographic self-registering instruments had been in constant operation a full year, and the number of readings of the several instruments observed by the eye was thereafter made five in a day instead of 24.

There are, besides, at the observatory lithographed and printed copies of the meteorological observations *in extenso* from September 1842 to December 1844, and from April 1845 to December 1846, and onward to 1864; but, as there is reason to believe that the hours to which the *printed* observations (of 1842 to 1844) produced under Dr. G. Buist's régime refer are the hours of Bombay time, whilst those to which the remainder of the observations refer are the hours of Göttingen time, it is of doubtful expediency to combine the two sets of observations together; and the observations of 1845 being of an incomplete year, and those of 1846 unreduced, it seemed to be undesirable to defer the utilization of the large body of later good results in order to prepare the observations of 1845 and 1846 for incorporation; it was resolved therefore to confine the discussion of all the phenomena, except rainfall, to the *manuscript* abstracts of the years 1844, and 1847 to 1872, which all have reference to Göttingen time.

15. *Checking of computations.*—Since the beginning of the year 1866, all computing operations have been systematically checked by a repetition of the operation by another computer, but it does not appear that previously any systematic check—other than an inspection of the results by the observatory senior assistants—was applied. The similar results of previous computations have, notwithstanding, been adopted as they appear on the abstract sheets; that is, the hourly and daily averages for each month, and the diurnal variations. The enormous labour of recomputing these for a period of twenty years would, if it had been undertaken, have rendered it quite impracticable to obtain any general conclusions in a reasonable time.

16. We proceed now to describe the several instruments in order; to mention such circumstances connected with their condition, situation, and adjustment as are requisite to enable the reader to form an independent judgment of the degree of precision attained, and of the weight to be attached to any conclusions drawn from the observations; and to describe and comment upon the results obtained. The treatment that we propose to apply to the observations of each meteorological element in succession is, first, to find the most probable absolute value of the element; secondly, to examine whether it is subject to any secular change which the observations are precise enough to exhibit; thirdly, to determine its periodical variations; fourthly, to determine its variability, and its range of variation, and the limits thereof, at different seasons; and, lastly, to exhibit all the results arrived at, as concisely as possible, by means of suitable diagrams. The elements that will be thus treated are barometric pressure, temperature of the air, pressure of vapour, temperature of the ground, rainfall, and direction and velocity of the wind; and observations of other phenomena, of less definiteness of character than these, or such as require less attention, will be treated in a less elaborate manner.

17. As a means of concise representation of phenomena of observational science, graphical constructions are greatly superior to verbal descriptions; for by means of them, the eye can take in, at one view, a body of facts which it would require a considerable effort of memory to retain and consider by a single mental operation, after verbal communication of them; and besides, in this way it is not only the absolute values of the phenomena that are presented before the eye, but their relations amongst each other, and, by comparison of similar representations of other phenomena, the relations of different phenomena. We regard it therefore as conducing to economy of mental effort to make a free use of graphical constructions; and such descriptions will be given of the several modes of representation by means of them as will make the figures readily comprehended. As an illustration of this conciseness of representation we would refer to the description given in paragraph 37 of the number of various relations indicated by the curves—all on a single page—numbered 192.

I. Barometer and Barometric Pressure.

18. *Description.*—The same barometer has been used uninterruptedly since the establishment of the observatory, the readings being taken throughout at from seven to nine minutes after the full hours of Bombay time. It is a standard by Newman, marked No. 58; and the internal diameter of the tube, marked by the maker on the frame of the instrument, is 0·530 inch. The scale, which is of brass, is moveable, and terminates below in an ivory point, which is carefully brought down by turning a slow-motion screw to the surface of the mercury in the cistern, and the point is known to be accurately in contact with the surface by its appearing just to meet its image reflected from the mercury. The upper part of the scale, which is divided to twentieths of an inch, has a vernier with slow-motion screw, reading to thousandths of an inch, and to it are attached two small brass plates with horizontal lower edges before and behind the tube. The setting of the instrument consists in raising and lowering the vernier until the horizontal plane containing these two edges is tangent to the surface of the mercury in

the tube of the barometer, and this is the case when it is just so low, and no lower, that when the eye is raised and lowered, no light is seen to pass between the central part of the mercurial surface and the two edges. A thermometer, with a cylindrical bulb dipping into the mercury in the cistern, is attached to the barometer, and is read at every observation.

19. The standard barometer is attached by means of brackets to a flat board, which hangs against the wall on the eastern side of the Magnetical Observatory, near the north-east corner of the room, and its cistern has an elevation of 37 feet above the mean sea level at Colába. It was lifted down and inverted on the 23rd July 1842, and on the 22nd January 1846, on the first occasion ejecting a bubble of air, and producing an increase of the barometric reading of more than a tenth of an inch, and on the second occasion producing no change whatever. Again in May 1866 it was lifted down and the mercury carefully caused to run up to the top of the tube, where it gave the sharp metallic stroke that is indicative of a good vacuum. It is stated in the Report of the Committee of Physics of the Royal Society, 1840, page 56, where a description is given of a class of barometer of which this is an individual, that the scale is laid off from the zero point from an authentic standard. Were it not therefore that the instrument is known to have had air in the tube, there would be no reason to presume that the absolute pressures observed with it differ very sensibly from the true pressures, but as the case stands, they must be regarded as subject to correction when an authentic standard becomes available for comparison with Newman, No. 58. Care has always been taken to preserve unchanged the adjustment of the instrument to verticality.

20. *Error in setting the zero point of the scale.*—In the long period that has elapsed since the instrument was mounted, there has been a gradual accumulation of scum on the surface of the mercury in the cistern, and the glass cistern has become more and more opaque, until at the present time the reflected image of the ivory zero point of the scale is very obscurely seen, so that the operation of setting the zero of the scale is uncertain to a very sensible degree. It was found from observations given on page xxvii of the "Introduction to the Bombay Magnetical and Meteorological Observations for 1864" that although an individual observer would make successive independent readings of the instrument which were consistent amongst themselves, yet that, owing to indistinctness in the reflection of the pointer, different practised observers differed from each other as much as ·026 inch.

21. *Change of method of observation.*—For this reason the method of observation, which had always previously been in accordance with the above description, was changed on the 22nd May 1866, so as to avoid the necessity of setting the scale at every observation. The scale was set once for all on that day, and the setting screw then removed, and suitable corrections were thereafter applied for the rise and fall of the mercury in the cistern. To determine the relative capacities of the tube and cistern the maker's value (0·530 inch) of the internal diameter of the tube was adopted as correct; and the internal diameter of the glass cistern and external diameter of the part of the tube dipping into

the mercury were assumed to be the same as those of the same parts of a similar broken barometer by the same maker; these were respectively 2·632 inches, and $\frac{2\cdot05}{3\cdot1416}$ inch. Hence an apparent rise of one inch, as shown on the barometer scale, will correspond to a real rise of $\left(1+\frac{(0\cdot53)^2}{(2\cdot632)^2-\left(\frac{2\cdot05}{3\cdot1416}\right)^2}\right)=1\cdot04321$ inch, and an apparent fall of one inch to a real fall of (1—·04321) inch; and the capacity correction will be ·01321 (h_0-h), h_0 being the observed reading, and h the reading for which the scale is correctly set. In order to set the scale so that the capacity correction should be nothing when the barometric pressure and temperature of the instrument have their mean values, the following means were adopted. First a series of hourly comparisons was made with the standard barometer No. 58, and a similar barometer No. 51, by the same maker, the mercury and cistern of which were rather cleaner than those of No. 58. The daily means, corrected to temperature 32°, of these hourly readings for seventeen days showed that No. 58 reads, on the average, ·011 inch lower than No. 51.

Now the mean barometric pressure is nearly 29·800 inches at temperature 32° or 29·943 at 82°·0, the mean temperature of the room in which the barometer is placed; and at the time the scale was permanently set, the mean of four readings of No. 51, taken by different observers, was 29·930; therefore the two barometers being similarly placed alongside of each other, and having the same temperature (about 87°·6), the reading of No. 58, corrected for capacity, must be ·011 less than 29·930 or 29·919; but the correction for capacity = ·043 (29·919—29·943) = —·001; hence the uncorrected reading of No. 58 must be made 29·920 by first placing the vernier so that its setting plane is tangent to the surface of the mercury in the tube, and then adjusting the scale by means of the lower screw to that reading. The scale was set to 29·914, and a suitable table of corrections constructed, which was used till noon on the 25th May 1866, when the scale was made to read ·006 higher, and a table of capacity corrections was used thereafter calculated by the formula—

$$\text{Correction} = \cdot04321\ (h_0-29\cdot943).$$

As the departure of the barometer reading from its mean value very rarely reaches 0·4 inch, which would require a correction of only ·017 inch, it is very improbable that an error of so much as ·001 inch ever occurs from inaccuracy in the adopted value of the relative capacities of the tube and cistern. Since the change was made, the comparability of the observations for showing variations is therefore throughout much better secured.

22. *Corrections applied to the observed readings.*—It was stated in the instructions given in the Report of the Committee of Physics (page 56) that the correction for capillary action in barometers of this description is rendered inappreciable by the large diameter of the tube; consequently no correction for capillarity has ever been applied, and the only corrections, besides those for capacity, which have been applied, and that invariably from the first, are for reducing the observations to what they would have been if the temperature of the mercury and brass scale had always been 32° Fahr., and these corrections were taken from Table II. of the Committee's Report.

23. *Mean absolute barometric pressure.* — The following table shows the mean barometric pressure reduced to temperature 32° Fahr., but not to sea level, in each month of the 26 years 1847 to 1872.

TABLE 1.

MONTHLY and ANNUAL MEAN VALUES of BAROMETRIC PRESSURE, expressed in inches of mercury at the temperature 32° Fahrenheit, for the 26 years 1847 to 1872.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual Mean.	Excess of Annual Mean above General Mean of 26 years.
1847	29·917	29·903	29·872	29·791	29·722	29·621	29·651	29·707	29·748	29·825	29·893	29·897	29·797	−·011
1848	·927	·916	·830	·770	·741	·649	·654	·706	·812	·826	·909	·922	·805	−·003
1849	·945	·906	·870	·779	·714	·624	·672	·700	·727	·841	·889	·911	·798	−·010
1850	·878	·927	·885	·816	·763	·639	·643	·736	·786	·785	·891	·949	·808	·000
1851	·958	·901	·857	·779	·739	·631	·599	·697	·782	·828	·838	·946	·796	−·012
1852	·929	·903	·829	·794	·746	·630	·660	·731	·756	·856	·905	·923	·805	−·003
1853	·940	·873	·859	·797	·775	·644	·673	·742	·793	·854	·863	·955	·814	+·006
1854	·935	·921	·885	·792	·760	·674	·618	·712	·715	·785	·923	·933	·804	−·004
1855	·935	·932	·853	·818	·787	·663	·658	·743	·787	·826	·939	·944	·824	+·016
1856	·985	·922	·835	·787	·718	·651	·610	·707	·799	·834	·897	·932	·806	−·002
1857	·930	·869	·831	·790	·735	·640	·649	·681	·811	·857	·918	·981	·808	·000
1858	·921	·939	·852	·798	·674	·698	·670	·720	·778	·822	·927	·944	·812	+·004
1859	·933	·918	·878	·787	·789	·662	·628	·731	·779	·854	·851	·931	·812	+·004
1860	·953	·875	·845	·827	·764	·650	·631	·725	·735	·809	·917	·919	·804	−·004
1861	·907	·897	·857	·764	·713	·666	·639	·689	·774	·857	·867	·932	·797	−·011
1862	·920	·871	·862	·801	·786	·634	·625	·689	·693	·780	·853	·887	·783	−·025
1863	·939	·883	·838	·746	·734	·606	·637	·697	·767	·811	·895	·947	·792	−·016
1864	·945	·923	·887	·821	·815	·674	·660	·742	·794	·867	·920	·931	·832	+·024
1865	·972	·910	·874	·800	·741	·669	·656	·666	·788	·848	·890	·918	·811	+·003
1866	·959	·905	·867	·816	·775	·675	·661	·706	·795	·808	·927	·969	·822	+·014
1867	·965	·916	·879	·819	·734	·671	·667	·692	·750	·826	·983	·981	·824	+·016
1868	·937	·921	·881	·831	·796	·673	·699	·742	·817	·857	·920	·963	·836	+·028
1869	·966	·936	·879	·821	·773	·659	·668	·705	·730	·824	·908	·904	·814	+·006
1870	·879	·877	·836	·795	·764	·651	·637	·724	·754	·807	·900	·936	·797	−·011
1871	·894	·891	·863	·793	·768	·641	·672	·733	·779	·821	·870	·932	·805	−·003
1872	·932	·907	·850	·776	·767	·640	·658	·677	·760	·820	·866	·892	·795	−·013
Mean	29·935	29·905	29·860	29·796	29·754	29·651	29·650	29·712	29·770	29·828	29·898	29·934	29·808	

For the first five months of 1847 the means are derived from observations at the even hours of the day only, the rest from hourly observations taken on every day of the year except Sundays and a few holidays.

The mean barometric pressure of the 26 years is 29·808 inches.

24. The series of annual means affords the following means for the five-year periods recommended for adoption by the Vienna Meteorological Congress:—

Five-year period.	Mean Barometric Pressure.
1851 to 1855	29·809
1856 to 1860	29·808
1861 to 1865	29·803
1866 to 1870	29·819

25. The mean for the 17 years from 1847 to 1865 is 29·806, and that for the seven years 1866 to 1872, 29·813. Perhaps the whole of this difference and a part of the excess of the mean for the five years 1866 to 1870 are due to the alteration made in May 1866 in the manner of using the barometer; for the maximum and minimum yearly pressures of the former periods (29·832 and 29·783) are also respectively less than the maximum and minimum pressures of the latter period (29·836 and 29·795): indeed it is easily conceivable and almost to be expected that the substitution of a definite for an indefinite observation would not only reduce the magnitude of errors of observations, but render such as remain more completely compensating in character. The range of variation of the annual means, viz. ·049 inch in the first 19 years, or ·053 inch if we combine the 26 years' observations, being much smaller than is experienced in middle-latitude stations in shorter periods, shows that the greater regularity which characterizes the movements of the barometer in tropical regions, as compared with middle-latitude regions, when short periods such as days are considered, is still clearly marked when the averages of long periods like a year are compared.

26. It appears from the excesses shown in the last column of Table 1 of the individual years' means above the general mean of all the years, that successions of years may be grouped together in a way to show a periodicity of very small range, which nearly corresponds in duration to the decennial sun-spot period, but is in advance of it in phase by about a quarter of a period: thus 1847 to 1852 give a mean defect of ·007; 1853 to 1859 a mean excess of ·003; 1860 to 1863 a mean defect of ·014; 1864 to 1869 a mean excess of ·015; and 1870 to 1872 a mean defect of ·009 inch; and the excesses for the winter half years, during which the secular variation is somewhat more regular than in the summer half years, are for the same periods — ·004; + ·005; — ·013; + ·017 and — ·017; showing the period in question even more strongly than the groups of yearly differences.

27. *Annual variation.*—In Table 2 are entered the mean barometric pressure for the 1st January in the 24 years 1847 to 1870, the mean for the 2nd January in the 24 years, the mean for the 3rd January, &c. &c., up to the 31st December; and these means

are curved (in black) in fig. 1, the ordinates of which represent pressure on a scale of 10 inches to an inch of pressure, and the obscissæ time as shown by the markings on the margin of the figure.

TABLE 2.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	November	December.
1	29·947	29·931	29·884	29·845	29·768	29·681	29·661	29·678	29·737	29·799	29·854	29·924
2	·947	·934	·885	·839	·774	·685	·655	·680	·735	·800	·848	·923
3	·949	·931	·869	·831	·781	·662	·645	·688	·737	·799	·860	·930
4	·947	925	·880	·824	·771	·681	·653	·698	·734	·808	·865	·924
5	·945	·920	·875	·827	·776	·690	·659	·714	·742	·806	·867	·935
6	·936	·927	·878	·814	·776	·671	·663	·703	·742	·795	·858	·915
7	·939	·928	·869	·810	·775	·682	·654	·689	·748	·804	·859	·918
8	·926	·934	·871	·800	·774	·647	·647	·702	·752	·819	·884	·925
9	·940	·907	·867	·797	·774	·634	·654	·717	·742	·810	·893	·922
10	·941	·906	·862	·799	·773	·635	·653	·700	·755	·830	·896	·927
11	·952	·905	·879	·798	·770	·637	·638	·690	·749	·812	·891	·932
12	·939	·917	·875	·803	·773	·651	·622	·686	·772	·826	·893	·929
13	·941	·906	·882	·803	·766	·628	·628	·686	·757	·818	·907	·916
14	·935	·904	·879	·805	·771	·635	·629	·696	·766	·838	·910	·928
15	·944	·907	·862	·793	·763	·643	·625	·713	·767	·836	·907	·935
16	·956	·901	·867	·796	·779	·639	·630	·731	·749	·836	·911	·938
17	·949	·903	·875	·797	·771	·636	·621	·719	·751	·827	·910	·945
18	·939	·907	·862	·789	·764	·620	·633	·717	·758	·835	·913	·947
19	·933	·908	·844	·781	·759	·640	·641	·728	·780	·836	·910	·942
20	·927	·905	·842	·782	·738	·648	·650	·723	·775	·823	·924	·941
21	·937	·897	·856	·784	·733	·639	·647	·719	·793	·826	·921	·946
22	·928	·887	·846	·776	·729	·637	·645	·719	·805	·826	·911	·946
23	·942	·885	·840	·786	·737	·651	·643	·714	·814	·825	·925	·946
24	·926	·889	·849	·780	·713	·649	·649	·731	·816	·824	·918	·955
25	·925	·887	·849	·779	·726	·662	·661	·745	·805	·835	·920	·954
26	·935	·880	·848	·784	·724	·658	·668	·740	·811	·858	·917	·944
27	·929	·871	·841	·781	·719	·657	·667	·737	·798	·865	·923	·946
28	·919	·877	·834	·773	·717	·651	·662	·745	·801	·873	·938	·946
29	·926		·835	·768	·711	·662	·670	·737	·789	·880	·931	·951
30	·926		·828	·777	·698	·665	·674	·714	·801	·860	·924	·951
31	·918		·832		·687		·668	·716		·856		·948

28. *Calculation of normal daily values.*—On an inspection of the (black) fig. 1 it is at once seen that in the course of the year there are strongly-marked systematic movements, upon which are superimposed movements of an irregular and oscillatory character, most of which it is reasonable to suspect would disappear with a great extension of the period of observation. Some means must be adopted of excluding the irregularities and obtaining from the means in Table 2 a series of smooth-flowing numbers, which shall represent the annual variation, apart from casual irregularities. The usual method of effecting this is to apply Bessel's process for finding an expression for a periodical phenomenon. This process

assumes that the law of variation may be expressed by the superposition of a series of simple variations whose periods are exact measures of the period of the observed phenomenon, *i.e.*, of once, a half, a third, a fourth, &c. of that period; and such an expression may be made to agree *exactly* with the observed values of the phenomenon at a certain number of equidistant intervals in the whole period, providing generally that the superposed variations are of number equal to half the number of observed values of the phenomenon. If then the expression be carried to its limit, so as to reproduce all the observed values of the phenomenon exactly, we reject nothing and therefore gain nothing in the way of removing what we assume to be casual departures from a regular flow of the true variation. But we have found a smooth-flowing variation, with risings and fallings of such frequency and magnitude that it takes in its course at their respective phases of the period all the observed values of the phenomenon. By rejecting, however, the subordinate variations of short period we shall get rid of the frequent risings and fallings, and there will remain a variation of the required smoothness of flow, and having only a few strongly-marked features in the course of the whole period. But if the number of observed values of the phenomenon be much greater than twice the number of subordinate variations retained, it will frequently be apparent that the law of variation inherent in the partial expression retained is inconsistent with some of the minor but systematic characteristics of the flow of the observed numbers, and that the general flow can be better exhibited by an arbitrary process. The process chosen in the present case involves the rejection from consideration of periodicities of 15 days' duration and less, and the contraction somewhat of the range of those of longer duration. The first step is to bring casual departures within closer range of the general course of the variation, and this is effected by the method adopted by the Astronomer Royal in reducing tracings of electrical earth currents. The 365 days' means are arranged in line, and under them and between each pair are placed the means of every successive pair, giving 365 new means. These we call the first smoothed means, and the operation the first smoothing operation; second, third, fourth, fifth, and sixth smoothed means are similarly calculated from the first, second, &c. smoothed means. Finally the mean is taken of the first 15 of the sixth smoothed means, and is put under the 8th January; the mean of the second to 16th of the sixth smoothed means is put under the 9th January, and so on, every day's final mean being the average of its own sixth smoothed mean, and of the seven preceding and seven following it; and for the first and last seven days of the year the sixth smoothed means of December and January are made to follow each other in circular order, the 1st January following the 31st December. The final means are shown in Table 3, and, for ready comparison, they are curved, in red ink, on the same form with figure 1.

TABLE 3.

Date.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
1	29·945	29·926	29·879	29·830	29·776	29·691	29·656	29·681	29·736	29·803	29·861	29·924
2	·944	·925	·878	·827	·775	·686	·656	·684	·737	·804	·865	·925
3	·944	·924	·876	·824	·775	·680	·655	·687	·738	·804	·867	·925
4	·944	·923	·876	·821	·774	·675	·654	·689	·739	·805	·869	·925
5	·943	·922	·875	·819	·774	·670	·652	·690	·741	·807	·871	·926
6	·943	·921	·875	·817	·773	·665	·650	·692	·743	·808	·873	·925
7	·942	·920	·875	·814	·773	·661	·648	·694	·745	·811	·876	·925
8	·942	·918	·874	·812	·773	·657	·646	·696	·748	·813	·880	·926
9	·942	·917	·873	·809	·773	·654	·644	·699	·750	·816	·883	·927
10	·942	·915	·872	·806	·773	·651	·642	·702	·751	·818	·887	·928
11	·942	·913	·871	·803	·772	·649	·641	·704	·753	·820	·891	·929
12	·941	·912	·870	·801	·771	·646	·639	·705	·755	·822	·894	·930
13	·940	·910	·868	·798	·769	·643	·639	·707	·758	·823	·898	·931
14	·940	·908	·866	·796	·766	·641	·638	·708	·761	·825	·901	·933
15	·939	·906	·864	·794	·763	·639	·637	·709	·765	·826	·905	·934
16	·939	·904	·863	·792	·760	·639	·637	·711	·769	·827	·907	·936
17	·939	·902	·861	·791	·757	·639	·637	·712	·773	·828	·909	·938
18	·938	·900	·860	·790	·754	·641	·638	·715	·777	·830	·911	·939
19	·937	·898	·858	·789	·751	·642	·640	·718	·780	·832	·913	·941
20	·936	·896	·856	·787	·748	·643	·642	·721	·783	·834	·915	·942
21	·935	·894	·853	·786	·744	·644	·644	·724	·785	·837	·917	·943
22	·934	·892	·850	·784	·740	·646	·647	·726	·788	·840	·918	·945
23	·933	·891	·848	·782	·735	·647	·650	·727	·790	·842	·919	·946
24	·931	·889	·846	·781	·729	·649	·653	·728	·793	·843	·920	·946
25	·930	·887	·844	·779	·724	·650	·656	·728	·796	·845	·921	·947
26	·929	·885	·842	·778	·718	·651	·660	·729	·798	·846	·922	·947
27	·929	·883	·841	·778	·713	·653	·663	·730	·800	·848	·923	·947
28	·928	29·881	·839	·777	·708	·654	·667	·731	·802	·850	·924	·947
29	·928		·838	·777	·705	·655	·671	·732	·803	·853	·924	·947
30	·927		·836	29·776	·701	29·655	·674	·734	29·803	·855	29·924	·947
31	·927		29·833		29·696		29·678	29·735		29·858		29·946
Monthly means	29·937	29·906	29·860	29·797	29·750	29·654	29·650	29·711	29·769	29·828	29·900	29·936

29. *Five-day means.*—We give also in Table 4, in accordance with the practice of the Meteorological Committee of the Board of Trade, the averages of five-day means of barometric pressure for the years 1847 to 1870.

TABLE 4.

Number of Five-day Period.	Corresponding Date.	Barometric Pressure.	Number of Five-day Period.	Corresponding Date.	Barometric Pressure.	Number of Five-day Period.	Corresponding Date.	Barometric Pressure.
1	January 1–5	29·947	25	May 1–5	29·774	50	September 3–7	29·741
2	6–10	·936	26	6–10	·774	51	8–12	·754
3	11–15	·942	27	11–15	·769	52	13–17	·758
4	16–20	·941	28	16–20	·762	53	18–22	·782
5	21–25	·932	29	21–25	·728	54	23–27	·809
6	26–30	·927	30	26–30	·714	55	28–32	·798
7	31–35	·928	31	31–35	·679	56	October 3–7	·802
8	February 5–9	·923	32	June 5–9	·665	57	8–12	·819
9	10–14	·908	33	10–14	·637	58	13–17	·831
10	15–19	·905	34	15–19	·636	59	18–22	·829
11	20–24	·893	35	20–24	·645	60	23–27	·841
12	25–29	·880	36	25–29	·658	61	28–32	·865
13	March 2–6	·877	37	30–34	·656	62	November 2–6	·860
14	7–11	·870	38	July 5–9	·655	63	7–11	·885
15	12–16	·873	39	10–14	·634	64	12–16	·906
16	17–21	·856	40	15–19	·630	65	17–21	·916
17	22–26	·846	41	20–24	·647	66	22–26	·918
18	27–31	·834	42	25–29	·666	67	27–31	·928
19	April 1–5	·833	43	30–34	·678	68	December 2–6	·925
20	6–10	·804	44	August 4–8	·701	69	7–11	·925
21	11–15	·800	45	9–13	·696	70	12–16	·929
22	16–20	·789	46	14–18	·715	71	17–21	·944
23	21–25	·781	47	19–23	·721	72	22–26	·949
24	26–30	29·777	48	24–28	·740	73	27–31	29·948
			49	29–33	29·728			

30. *Bessel's coefficients and annual variation yielded by them.*—From the numbers in this table, and taking $\frac{360^\circ}{73}$ as the angle corresponding to five days, have been calculated the coefficients of Bessel's formula, including terms of periods of one year, six months, four months, &c., to two months. Inserting these the formula becomes

$$B = 29{\cdot}8078 + 0{\cdot}1405 \sin(\theta + 87^\circ\ 2') + 0{\cdot}0117 \sin(2\theta + 252^\circ\ 15') + 0{\cdot}0132 \sin(3\theta + 105^\circ\ 16') + 0{\cdot}0072 \sin(4\theta + 284^\circ\ 3') + 0{\cdot}0037 \sin(5\theta + 161^\circ\ 43') + 0{\cdot}0047 \sin(6\theta + 17^\circ\ 23'),$$

in which θ is measured from the 3rd January, and by means of it have been calculated the values for every fifth day in the year as shown in Table 5.

TABLE 5.

Number of Five-day Period.	Corresponding Date.	Barometric Pressure calculated.	Number of Five-day Period.	Corresponding Date.	Barometric Pressure calculated.	Number of Five-day Period.	Corresponding Date.	Barometric Pressure calculated.
1	January 1–5	29·945	25	May 1–5	29·777	50	September 3–7	29·750
2	6–10	·945	26	6–10	·769	51	8–12	·761
3	11–15	·943	27	11–15	·758	52	13–17	·771
4	16–20	·940	28	16–20	·744	53	18–22	·781
5	21–25	·935	29	21–25	·728	54	23–27	·789
6	26–30	·929	30	26–30	·710	55	28–32	·797
7	31–35	·922	31	31–35	·691	56	October 3–7	·805
8	February 5–9	·915	32	June 5–9	·674	57	8–12	·814
9	10–14	·909	33	10–14	·658	58	13–17	·824
10	15–19	·902	34	15–19	·646	59	18–22	·835
11	20–24	·896	35	20–24	·638	60	23–27	·847
12	25–29	·889	36	25–29	·634	61	28–32	·860
13	March 2–6	·882	37	30–34	·635	62	November 2–6	·874
14	7–11	·874	38	July 5–9	·639	63	7–11	·887
15	12–16	·865	39	10–14	·646	64	12–16	·898
16	17–21	·855	40	15–19	·653	65	17–21	·908
17	22–26	·843	41	20–24	·662	66	22–26	·917
18	27–31	·832	42	25–29	·670	67	27–31	·923
19	April 1–5	·821	43	30–34	·679	68	December 2–6	·928
20	6–10	·811	44	August 4–8	·687	69	7–11	·933
21	11–15	·802	45	9–13	·696	70	12–16	·937
22	16–20	·795	46	14–18	·706	71	17–21	·939
23	21–25	·789	47	19–23	·716	72	22–26	·942
24	26–30	29·783	48	24–28	·727	73	27–31	29·944
			49	29–33	29·739			

These numbers are curved, in violet ink, on the same form with fig. 1. It will be noticed that they are less in agreement with the original means than those calculated by the arbitrary process. For this reason, the latter are to be preferred for present employment, as indicating the normal barometric pressure at the different seasons of the year, and accordingly they are the normals to which the abnormal pressures, hereafter to be dealt with, have reference.

31. The annual variation of normal barometric pressure follows very closely the law of sines, with maximum pressure occurring about the 1st January and minimum about the 1st July; this may be inferred from the values of Bessel's coefficients, the first of which is + 0·14, while the resultant of the first pair is still 0·14, and the resultant of the next five pairs each less than a tenth of 0·14. The principal interruptions to this law are an almost complete arrestation of the fall of the barometer from the 25th April to the 13th May, followed by a compensating more rapid fall till near the middle of June, and a very marked reverse oscillation between the middle of June and middle of July, having a maximum at the beginning of July, and a range of ·02 inch of mercury. The greatest normal daily pressure (29·947) occurs from December 25 to 30, and the least (29·637) from July 15 to 17, giving a range in the year of 0·310 inch.

The excess of the greatest monthly mean above the least monthly mean varies, in the different years, between ·375 and ·274 inch, the former difference being for 1856 and the latter for 1858; hence we know that the range of the annual variation would be sensibly different if determined from several shorter periods of observation.

32. *Variation in period of one-eighth of a year.*—Comparing our normal variation curve (in red) with the curve (in violet) yielded by six pairs of terms of Bessel's formula, we notice that the differences persistently indicate the existence of a period of one-eighth of a year, having maxima at the beginning and middle of the year: it is not of the simple kind, having the same amplitude of variation in each repetition of the period, that would be removed by the extension of Bessel's formula to eight pairs of terms; but its amplitude is great in the middle of the year, and small at the beginning, so that it would be pretty correctly expressed by a term of the form $(A - B \cos \theta) \cos 8\theta$, in which A and B are positive, and B less than A. It may be mentioned that contemporaneously with the upward inflexion of the normal curve, about the middle of May, due to this period, there are small but distinct downward inflexions of the normal temperature and pressure of vapour curves, and of the normal curve of the east component of the wind.

33. *Diurnal variation.*—The mean diurnal variation of barometric pressure, for the 24 Januaries of 1844 and 1848 to 1870, is expressed in the following table by the algebraical excess of the pressure at each hour of the day above the mean pressure of the 24 hours; so also are the mean diurnal variations for the other months, for the summer months together, for the winter months together, and for all the months together, but with this difference, that from June to December the means are for 25 years, including 1847.

TABLE 6.

Hours of Civil Time.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	April to Sept.	Oct. to March.	Year.
h. m.															
0 8	+·002	+·006	+·005	+·003	+·003	+·008	+·006	+·005	+·004	−·001	−·001	+·001	+·005	+·002	+·003
1 „	−·008	−·007	−·008	−·007	−·011	−·008	−·009	−·012	−·011	−·014	−·014	−·010	−·009	−·010	−·010
2 „	−·020	−·021	−·021	−·020	−·022	−·022	−·023	−·025	−·024	−·023	−·025	−·021	−·022	−·022	−·022
3 „	−·029	−·029	−·028	−·026	−·026	−·030	−·030	−·032	−·031	−·027	−·030	−·029	−·029	−·029	−·029
4 „	−·029	−·029	−·027	−·023	−·021	−·027	−·030	−·031	−·029	−·023	−·026	−·028	−·027	−·027	−·027
5 „	−·021	−·019	−·015	−·010	−·010	−·019	−·024	−·023	−·018	−·012	−·013	−·018	−·017	−·016	−·017
6 „	−·004	−·001	+·005	+·010	+·010	·000	−·007	−·007	−·003	+·010	+·009	−·001	+·001	+·003	+·002
7 „	+·023	+·025	+·029	+·032	+·031	+·016	+·006	+·010	+·020	+·032	+·033	+·026	+·019	+·028	+·023
8 „	+·049	+·049	+·052	+·053	+·046	+·030	+·023	+·028	+·040	+·051	+·055	+·052	+·037	+·051	+·044
9 „	+·069	+·068	+·066	+·063	+·055	+·039	+·031	+·038	+·050	+·062	+·069	+·068	+·046	+·067	+·056
10 „	+·067	+·071	+·066	+·059	+·053	+·039	+·034	+·041	+·049	+·058	+·062	+·065	+·046	+·064	+·055
11 „	+·049	+·053	+·051	+·047	+·043	+·033	+·029	+·035	+·040	+·037	+·041	+·045	+·038	+·046	+·042
12 „	+·018	+·024	+·025	+·026	+·027	+·022	+·020	+·021	+·020	+·009	+·009	+·014	+·023	+·016	+·019
13 „	−·014	−·009	−·005	−·001	+·002	+·007	+·008	+·003	−·004	−·017	−·021	−·018	+·003	−·014	−·006
14 „	−·037	−·035	−·031	−·027	−·019	−·011	−·006	−·013	−·025	−·040	−·041	−·039	−·016	−·037	−·027
15 „	−·049	−·051	−·050	−·046	−·038	−·027	−·020	−·027	−·039	−·051	−·051	−·050	−·032	−·050	−·042
16 „	−·050	−·053	−·054	−·055	−·049	−·037	−·030	−·035	−·043	−·050	−·050	−·051	−·041	−·051	−·046
17 „	−·043	−·046	−·050	−·053	−·046	−·036	−·028	−·030	−·036	−·039	−·039	−·041	−·038	−·043	−·041
18 „	−·031	−·035	−·039	−·040	−·034	−·025	−·019	−·019	−·023	−·026	−·025	−·028	−·026	−·030	−·029
19 „	−·011	−·016	−·022	−·026	−·020	−·011	−·006	−·006	−·006	−·005	−·004	−·007	−·012	−·011	−·012
20 „	+·008	+·005	−·002	−·006	−·004	+·005	+·007	+·008	+·011	+·014	+·013	+·011	+·004	+·008	+·006
21 „	+·023	+·018	+·015	+·010	+·010	+·018	+·018	+·021	+·025	+·022	+·021	+·021	+·017	+·020	+·018
22 „	+·023	+·022	+·020	+·018	+·018	+·026	+·025	+·026	+·026	+·021	+·020	+·022	+·024	+·021	+·022
23 „	+·012	+·015	+·015	+·013	+·013	+·021	+·018	+·019	+·018	+·012	+·009	+·012	+·018	+·012	+·014

34. *Bessel's coefficients.*—From the numbers in Table 6 have been calculated, by Bessel's method, the values of the coefficients in the following expressions* for the diurnal variations, in which θ represents the hour, reckoned from eight minutes after midnight, and converted into arc at the rate of 15° per hour.

TABLE 7.

January	$\Delta B = \cdot0204 \sin(\theta + 334^\circ\ 26') + \cdot0429 \sin(2\theta + 162^\circ\ 37') + \cdot0066 \sin(3\theta + 3^\circ\ 28') + \cdot0034 \sin(4\theta + 258^\circ\ 1') + \&c.$
February	$\Delta B = \cdot0230 \sin(\theta + 335\ 6) + \cdot0440 \sin(2\theta + 158\ 41) + \cdot0050 \sin(3\theta + 5\ 43) + \cdot0023 \sin(4\theta + 221\ 25) + \&c.$
March	$\Delta B = \cdot0260 \sin(\theta + 336\ 12) + \cdot0421 \sin(2\theta + 157\ 31) + \cdot0024 \sin(3\theta + 24\ 27) + \cdot0013 \sin(4\theta + 218\ 40) + \&c.$
April	$\Delta B = \cdot0280 \sin(\theta + 337\ 6) + \cdot0388 \sin(2\theta + 156\ 56) + \cdot0008 \sin(3\theta + 104\ 2) + \cdot0004 \sin(4\theta + 303\ 41) + \&c.$
May	$\Delta B = \cdot0242 \sin(\theta + 331\ 51) + \cdot0351 \sin(2\theta + 157\ 14) + \cdot0017 \sin(3\theta + 173\ 17) + \cdot0004 \sin(4\theta + 63\ 26) + \&c.$
June	$\Delta B = \cdot0117 \sin(\theta + 321\ 34) + \cdot0320 \sin(2\theta + 153\ 2) + \cdot0037 \sin(3\theta + 172\ 18) + \cdot0006 \sin(4\theta + 45\ 0) + \&c.$
July	$\Delta B = \cdot0081 \sin(\theta + 290\ 53) + \cdot0290 \sin(2\theta + 151\ 8) + \cdot0028 \sin(3\theta + 169\ 31) + \cdot0006 \sin(4\theta + 350\ 32) + \&c.$
August	$\Delta B = \cdot0095 \sin(\theta + 303\ 51) + \cdot0326 \sin(2\theta + 155\ 33) + \cdot0013 \sin(3\theta + 180\ 0) + \cdot0007 \sin(4\theta + 188\ 8) + \&c.$
September	$\Delta B = \cdot0135 \sin(\theta + 328\ 53) + \cdot0377 \sin(2\theta + 161\ 17) + \cdot0007 \sin(3\theta + 333\ 26) + \cdot0008 \sin(4\theta + 240\ 15) + \&c.$
October	$\Delta B = \cdot0201 \sin(\theta + 343\ 49) + \cdot0406 \sin(2\theta + 171\ 31) + \cdot0032 \sin(3\theta + 3\ 35) + \cdot0017 \sin(4\theta + 256\ 46) + \&c.$
November	$\Delta B = \cdot0213 \sin(\theta + 339\ 57) + \cdot0427 \sin(2\theta + 172\ 20) + \cdot0049 \sin(3\theta + 16\ 35) + \cdot0022 \sin(4\theta + 254\ 3) + \&c.$
December	$\Delta B = \cdot0201 \sin(\theta + 338\ 25) + \cdot0429 \sin(2\theta + 165\ 58) + \cdot0061 \sin(3\theta + 10\ 23) + \cdot0030 \sin(4\theta + 254\ 35) + \&c.$
April to September	$\Delta B = \cdot0154 \sin(\theta + 325\ 35) + \cdot0341 \sin(2\theta + 156\ 8) + \cdot0015 \sin(3\theta + 168\ 41) + \cdot0001 \sin(4\theta + 270\ 0) + \&c.$
October to March	$\Delta B = \cdot0218 \sin(\theta + 337\ 54) + \cdot0423 \sin(2\theta + 164\ 39) + \cdot0047 \sin(3\theta + 9\ 52) + \cdot0022 \sin(4\theta + 245\ 46) + \&c.$
Year	$\Delta B = \cdot0184 \sin(\theta + 332\ 53) + \cdot0381 \sin(2\theta + 160\ 51) + \cdot0017 \sin(3\theta + 17\ 21) + \cdot0012 \sin(4\theta + 250\ 1) + \&c.$

35. And from the expressions in the last three lines have been calculated, by the usual process of differentiation and successive approximation, the times of occurrence of the maxima and minima of the mean diurnal variations for the year, and for the two half years, and thence the diurnal inequalities of the height at those times. These are as follows :—

	Maximum.				Minimum.			
	First.		Second.		First.		Second.	
	Time of Occurrence.	Inequality.	Time of Occurrence.	Inequality.	Time of Occurrence.	Inequality.	Time of Occurrence.	Inequality.
	h. m.		h. m.		h. m.		h. m.	
April to September	9 43	+·047	22 8	+·021	3 25	−·030	16 27	−·041
October to March	9 31	+·068	21 51	+·021	3 31	−·028	15 48	−·052
Year	9 35	+·057	21 58	+·021	3 28	−·029	16 7	−·046

* In Table 87, these expressions, as well as corresponding ones relating to other phenomena, are repeated in the form $\Delta B = p_1 \cos\theta + q_1 \sin\theta + p_2 \cos 2\theta + q_2 \sin 2\theta + p_3 \cos 3\theta + q_3 \sin 3\theta + p_4 \cos 4\theta + q_4 \sin 4\theta +$, &c.

36. The numbers in Table 6 are curved in figures 24 to 38, in which, making use of the times and heights of maximum and minimum just referred to, we notice the following remarkable features: first, at all seasons of the year the movements of the barometer are very regular, exhibiting a double oscillation in the 24 hours; secondly, the mean diurnal variation for the year acquires a maximum of + ·057 inch at 9h. 35m. a.m., a minimum of — ·046 inch at 4h. 7m. p.m., a maximum of + ·021 inch at 9h. 58m. p.m., and a minimum of — ·029 inch at 3h. 28m. a.m., these being all reckoned above or below the normal pressure (29·808 inches) of the year; thirdly, the night oscillation is sensibly uniform throughout the year, except that the maximum turning point is, on the average, later in the summer than in the winter months by 17 minutes; fourthly, the day oscillation is extended or contracted on both sides of the zero of diurnal movement in subjection to an annual period, so that whilst its range for the months from November to April is ·120 inch, it is in the months June to August only ·072 inch, and in July only ·064 inch, and in May, September, and October its range is intermediate between the two former values; lastly, the time of occurrence of the morning maximum and of the afternoon minimum is on the average of the months April to September later than on the average of the months January to March and October to December by ·12 minutes and 39 minutes respectively.

37. It is desirable, however, to exhibit the relative as well as the absolute character of the diurnal variations at the different seasons of the year, and these curves, whilst fully answering the latter purpose, only convey general impressions in regard to the former. The set of curves numbered 192 have been constructed to supply the deficiency: their ordinates, measured horizontally, represent excesses of pressure above the mean of the 24 hours, and their abscissæ, measured vertically, the seasons* of the year; the curves represent the hours of the day, and the course of them indicates whether and to what extent, as the seasons advance, the hourly inequalities increase or decrease; symmetry of form in successive hourly curves implies a similarity in the mode of progression of the diurnal variation at different seasons, and parallelism implies an equal rate of rise or fall of the barometer between the hours for which it holds throughout the year; the absence of symmetry or parallelism in successive hourly curves shows the extent of dissimilarity in the growth or diminution of the diurnal inequality, or the inequality of rate of that growth or diminution at different seasons; the distance between two successive hourly curves measures the rise or fall of the barometer in that hour, being a rise if the later hour's curve be to the right of the earlier, and a fall if to the left; the length of the horizontal line from the curve on the extreme left to the curve on the extreme right, at the height representing a particular month, shows the range of the diurnal variation of barometric pressure in that month.

38. We notice a considerable approach to symmetry of form, with a gradually changing type, in the successive curves of the hours 4 to 11; at first the type shows minimum values of the inequalities about July and January, and maximum values about midway between

* For lack of a better term the word "seasons" is used here and elsewhere, not in its usual limited sense only, but to indicate any divisions of the year, as months, fortnights, days, &c.

those months; at last the minimum about July alone remains, and there is only one maximum, which occurs about January. There is also some approach to symmetry in the curves of the hours 13 to 15, showing maxima about July, and minima between October and November. The curves of 17 and 18 hours show maxima about July, and minima about April, whilst in those of 19 to 21 hours the minimum inflexion about April is the only striking feature. The curves of the hours 22 to 3 all approximate to vertical straight lines, and those of 12 hours and 16 hours modulate into those of the preceding and following hours.

39. In illustration of the verbal interpretation of these curves we may state that they imply, as we have already inferred, from figs. 24 to 38, that the character and extent of the diurnal variation between the time of the evening maximum and morning minimum is—notwithstanding a small but well-marked excess of range at the solstices as compared with the equinoxes—nearly the same throughout the year; that for the remainder of the day it varies with the season, not only by a general increase of movement from midsummer to midwinter, but by a wide departure from proportionality in the changes from hour to hour; that at the hours 18 to 21 the barometer stands further below or less above its mean height about April than at any other time of the year, and that at 13 and 14 hours the depression below the mean is greatest about November. In the same manner the considerable deviations from any simple type of annual variation of the inequalities at the different hours, shown by the other hours' curves, may be expressed in ordinary language, but they are more readily conceived when examined by means of the graphical symbolization. The growth of the inequalities between the hours 4 and 7 appears to possess a significant relation to the inequalities of the east component of the wind for the same hours, for in both variations the minima occur about the solstices, and the maxima about the equinoxes, and in both after 7 hours the characteristics referred to begin to subside.

40. In individual years the greatest and least ranges of the mean diurnal variation for the year are ·107 inch and ·098 inch, showing a difference of about a tenth of the whole range; and the average difference between the greatest and least ranges for the several months is ·023 inch, or nearly a fourth of the average range. From these facts it will readily be inferred that so large a body of hourly observations as is accumulated in a quarter of a century, even where the barometer is so regular in its movements as at Bombay, is not greater than is necessary for the elimination of casual irregularities, by which is here meant deviations in the character and range of the diurnal variation as determined from individual day's observations from the typical character and range due to the particular season.

41. *Variability.*—We now subjoin a table showing the greatest and least barometric pressure which was observed in each of the years from 1847 to 1872; first, at any individual hour, in any month; secondly, as to daily means in any month; and, thirdly, as to monthly means.

TABLE 8.

Year.	Individual Hours.								Daily Means.							Monthly Means.				
	Maximum.				Minimum.				Extreme range in Year.	Maximum.			Minimum.			Range in Year.	Maximum.		Minimum.		Range in Year.
	Pressure.	Time of Occurrence.			Pressure.	Time of Occurrence.				Pressure.	Date of Occurrence.		Pressure.	Date of Occurrence.			Pressure.	Month.	Pressure.	Month.	
	inches.	hr.	day.	mth.	inches.	hr.	day.	mth.	inches.	inches.	day.	mth.	inches.	day.	mth.	inches.	inches.		inches.		inches.
1847	30·075	10	3	2	29·458	16	24	6	·617	30·017	1	1	29·498	23	6	·519	29·917	1	29·621	6	·296
1848	30·094	9	28	11	29·445	16	18	6	·639	30·012	9	2	29·491	18	6	·521	29·927	1	29·649	6	·278
1849	30·094	21	19	12	29·387	4	23	6	·707	30·016	19	12	29·428	22	6	·588	29·945	1	29·624	6	·321
1850	30·070	9	17	12	29·482	18	11	6	·588	29·998	21	11	29·521	23	7	·477	29·949	12	29·639	6	·310
1851	30·148	10	14	1	29·414	4	11	6	·734	30·036	13	1	29·462	10	6	·574	29·958	1	29·599	7	·359
1852	30·072	10	5	2	29·433	16	18	6	·639	30·001	26	1	29·485	18	6	·516	29·929	1	29·630	6	·299
1853	30·113	9	28	12	29·502	17	13	7	·611	30·022	28	12	29·536	14	7	·486	29·955	12	29·644	6	·311
1854	30·111	10	18	2	29·183	4	2	11	·928	30·031	18	2	29·514	14	7	·517	29·935	1	29·618	7	·317
1855	30·119	9	1	2	29·462	16	3	7	·657	30·048	31	1	29·513	3	7	·535	29·944	12	29·658	7	·286
1856	30·136	8	10	1	29·439	16	30	5	·697	30·068	10	1	29·524	1	6	·544	29·985	1	29·610	7	375
1857	30·105	9	29	12	29·507	4	23	6	·598	30·039	6	1	29·541	23	6	·498	29·981	12	29·640	6	·341
1858	30·093	10	1	1	29·464	16	20	5	·629	30·018	30	12	29·516	19	5	·502	29·944	12	29·670	7	·274
1859	30·061	9	24	12	29·437	16	16	7	·624	29·994	24	12	29·492	22	7	·502	29·933	1	29·628	7	·305
1860	30·095	9	28	11	29·452	18	12	6	·643	30·012	23	1	29·496	12	6	·516	29·953	1	29·631	7	·322
1861	30·053	9	27	12	29·429	4	1	6	·624	29·975	2	1	29·506	1	6	·469	29·932	12	29·639	7	·293
1862	30·101	10	31	12	29·467	3	16	6	·634	30·017	31	12	29·511	16	6	·506	29·920	1	29·625	7	·295
1863	30·108	9	28	1	29·457	3	22	6	·651	30·018	28	1	29·500	8	7	·518	29·947	12	29·606	6	·341
1864	30·142	9	5	2	29·486	16	9	6	·656	30·054	5	2	29·567	19	7	·487	29·945	1	29·660	7	·285
1865	30·109	10	16	1	29·456	4	3	7	·653	30·039	16	1	29·496	3	7	·543	29·972	1	29·656	7	·316
1866	30·164	9	24	12	29·342	3	18	6	·822	30·076	24	12	29·452	18	6	·624	29·969	12	29·661	7	·308
1867	30·143	9	14	11	29·514	17	14	6	·629	30·058	14	11	29·564	19	7	·494	29·983	11	29·667	7	·316
1868	30·131	9	18	12	29·344	3	8	6	·787	30·053	17	12	29·413	8	6	·640	29·963	12	29·673	6	·290
1869	30·132	10	15	1	29·463	3	19	7	·669	30·046	15	1	29·503	19	7	·543	29·966	1	29·659	6	·307
1870	30·094	9	6	12	29·418	16	18	6	·676	30·015	8	12	29·478	18	6	·537	29·936	12	29·637	7	·299
1871	30·068	10	19	1	29·466	15	8	6	·602	29·996	19	1	29·521	9	6	·475	29·932	12	29·641	6	·291
1872	30·067	9	26	12	29·515	17	3	5	·552	29·980	26	12	29·569	13	7	·411	29·932	1	29·640	6	·292

In this and other similar tables, if the maximum or minimum occurs on more than one occasion, the time of the first occurrence only is noted.

The greatest pressure at any hour in the period of 26 years is 30·164 inches, and was observed at 9 a.m. on the 24th December 1866; the least was 29·183, observed at 4 a.m. on the 2nd November 1854; the greatest mean daily pressure was 30·068 on the 10th January 1856, and the least 29·413 on the 8th June 1868; and the greatest monthly mean pressure was 29·985 for January 1856, and the least 29·599 for July 1851.

Figure 194 represents the pressures shown in Table 8, the red lines referring to the hourly observations, the black lines to the daily means, and the violet lines to the monthly means; and within the several ranges whose limits are marked by the extremities of the lines lay every value of each kind respectively observed during the whole period. The maxima—hourly, daily, and monthly—exhibit a decennial variation possessing the same characteristics as are described in paragraph 26 as attaching to a variation of the mean

annual barometric pressure. The means of maxima for the several groups of years are as follows:—

Maxima.	1847 to 1852.	1853 to 1859.	1860 to 1863.	1864 to 1869.	1870 to 1872.
Hourly - -	30·090	30·105	30·089	30·137	30·076
Daily - -	30·013	30·031	30·005	30·054	29·997
Monthly - -	29·937	29·954	29·938	29·966	29·933

42. In Table 9 are collected the extreme values of barometric pressure which were observed in each month of any of the 26 years.

Table 9.

Month.	Individual Hours.					Daily Means.				
	Maximum.		Minimum.		Extreme Range in Month.	Maximum.		Minimum.		Range in Month.
	Pressure.	Time of Occurrence.	Pressure.	Time of Occurrence.		Pressure.	Date of Occurrence.	Pressure.	Date of Occurrence.	
	inches.	hr. day. yr.	inches.	hr. day. yr.	inches.	inches.	date. year.	inches.	date. year.	inches.
January - -	30·148	10 14 1851	29·677	3 16 1871	·471	30·068	10 1856	29·755	16 1871	·313
February -	30·142	9 5 1864	29·721	17 27 1857	·421	30·054	5 1864	29·781	27 1862	·273
March - -	30·062	10 13 1866	29·630	16 29 1849	·432	29·985	13 1866	29·723	29 1849	·262
April - -	30·053	9 2 1868	29·588	16 27 1859	·465	29·964	2 1868	29·649	30 1851	·315
May - -	29·948	10 4 1864	29·439	16 30 1856	·509	29·884	4 1864	29·516	19 1858	·368
June - -	29·910	9 4 1866	29·342	3 18 1866	·568	29·845	4 1866	29·413	8 1868	·432
July - -	29·869	10 29 1853	29·437	16 16 1859	·432	29·829	29 1853	29·485	17 1851	·344
August - -	29·918	9 8 1859	29·479	15 3 1849	·439	29·864	26 1871	29·516	2 1849	·348
September -	29·998	9 26 1857	29·484	16 21 1870	·514	29·938	26 1857	29·545	17 1849	·393
October - -	30·051	9 30 1858	29·531	16 6 1854	·520	29·970	30 1858	29·586	6 1854	·384
November -	30·143	9 14 1867	29·183	4 2 1854	·960	30·058	14 1867	29·631	2 1854	·427
December -	30·164	9 24 1866	29·713	16 4 1872	·451	30·076	24 1866	29·778	4 1872	·298

These extremes are represented by the lines of fig. 195 in the same manner as those of Table 8 are represented by the lines of fig. 194. The hurricane which visited Bombay on the 1st–2nd November 1854 was a unique occurrence in the whole period of observation; and this not only in that it simply exceeded in severity any other storm of the period, but in that it very far surpassed the next greatest storm both in the violence with which the wind blew and in the extent of the barometric depression; it lasted, however, but about 12 hours, from 8 p.m. of the 1st to 8 a.m. of the 2nd November, and during this short time only was the barometric pressure more than 0·2 inch below the normal pressure of the season. To mark the extravagance of this particular movement of the barometer, the portions of the lines in figs. 194 and 195 that are due to it are made discontinuous. It will be seen that the depression was 0·481 inch below the next lowest pressure in the month of November in any year, and 0·256 inch below any other pressure in any month.

43. But the extreme values of barometric pressure are nearly approached on very few occasions in the whole period of observation, and a necessary element of a complete knowledge of the behaviour of the barometer is the relative frequency of occurrence of pressures between successive near limits, say between limits having an interval of ·025 inch of mercury.

In the following table are shown the numbers of occurrences of mean daily pressures in each fortieth of an inch of the barometer scale during the same fortnight in all the years 1847 to 1870, and for each fortnight in the year.

TABLE 10.

Mean Daily Pressure lying between	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		December.	
	FORTNIGHT.																							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
30·075 and 30·099																								1
30·050 and 30·074	2	2	1																		1			1
30·025 and 30·049	3	5	6	1																		6	2	8
30·000 and 30·024	18	14	6	1																	2	9	13	19
29·975 and 29·999	49	35	26	4	1	1															7	24	24	45
29·950 and 29·974	66	64	35	19	1		2													5	14	54	43	71
29·925 and 29·949	61	65	54	32	28	9												1	2	14	40	57	77	62
29·900 and 29·924	41	61	64	66	45	23	7	1										2	10	26	46	61	60	56
29·875 and 29·899	28	48	43	72	71	57	14	2	6								2	11	33	41	60	40	47	31
29·850 and 29·874	16	27	32	42	70	67	30	24	8	1					3	6	9	35	53	60	45	30	25	6
29·825 and 29·849	9	7	16	32	45	60	68	36	24	16	2			1	1	2	24	38	47	68	30	19	9	2
29·800 and 29·824	1	1	4	14	22	49	66	52	57	20	3	1	2	3	7	17	22	73	50	44	28	6	5	4
29·775 and 29·799	2			4	8	33	54	65	50	43	5	10	7	3	9	31	45	50	37	25	13	2	1	
29·750 and 29·774					2	14	33	50	59	56	18	15	15	11	30	59	57	36	30	14	6	3		
29·725 and 29·749						3	15	32	54	56	15	21	13	22	37	62	47	24	25	11	4			
29·700 and 29·724						1	7	21	30	41	35	33	19	32	59	48	44	10	10	5	1	1		
29·675 and 29·699							3	15	10	35	47	32	38	34	49	42	19	6	6	3				
29·650 and 29·674								7	6	8	43	43	49	45	36	35	14	4	4	1				
29·625 and 29·649								1	1	18	41	49	51	67	33	12	14	5		1	1			
29·600 and 29·624									2	7	41	29	46	45	19	5	3	6	2					
29·575 and 29·599										7	20	20	30	31	9	3	5	3	1					
29·550 and 29·574									1	3	19	17	13	18	4	2	1	2						
29·525 and 29·549										3	7	17	17	6	1			2						
29·500 and 29·524										2	5	11	6	7	1									
29·475 and 29·499											2	9	2	2										
29·450 and 29·474											1	1												
29·425 and 29·449											1	1												
29·400 and 29·424											1													
Totals	296	329	287	287	293	317	299	306	308	316	306	309	308	327	298	324	306	308	310	318	298	312	306	306

44. And in the next table the numbers in each column of Table 10 have been divided by the total number of days of observation in the particular fortnight, giving quotients which represent probabilities of occurrence of mean daily pressure within each of the limits, on a scale in which unity stands for certainty of occurrence.

TABLE 11.

PROBABILITIES of OCCURRENCE of MEAN DAILY PRESSURES within each fortieth of an inch of the Barometer Scale.

Mean Daily Pressure lying between	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	FORTNIGHT.																							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
30·075 and 30·099																								·003
30·050 and 30·074	·007	·006	·003																		·003			·003
30·025 and 30·049	·010	·015	·021	·003																		·019	·007	·026
30·000 and 30·024	·061	·043	·021	·003																	·007	·029	·042	·062
29·975 and 29·999	·166	·106	·091	·014	·003	·003															·023	·077	·078	·147
29·950 and 29·974	·223	·195	·122	·066	·003		·007													·016	·047	·173	·141	·232
29·925 and 29·949	·206	·198	·189	·111	·096	·028												·003	·006	·044	·134	·183	·252	·203
29·900 and 29·924	·139	·185	·223	·230	·154	·073	·023	·003										·006	·032	·082	·154	·196	·196	·183
29·875 and 29·899	·095	·146	·150	·251	·242	·180	·047	·007	·019								·007	·036	·106	·129	·201	·128	·154	·101
29·850 and 29·874	·054	·082	·111	·146	·239	·211	·100	·078	·026	·003					·010	·019	·029	·114	·171	·189	·151	·096	·082	·020
29·825 and 29·849	·030	·021	·056	·111	·154	·189	·227	·118	·078	·051	·007			·003	·003	·006	·078	·123	·152	·214	·101	·061	·029	·007
29·800 and 29·824	·003	·003	·014	·049	·075	·155	·221	·170	·185	·063	·010	·003	·006	·009	·024	·052	·072	·237	·161	·138	·094	·019	·016	·013
29·775 and 29·799	·007			·014	·027	·104	·181	·212	·162	·136	·016	·032	·023	·009	·030	·096	·147	·162	·119	·079	·044	·006	·003	
29·750 and 29·774					·007	·044	·110	·163	·192	·177	·059	·049	·049	·034	·101	·182	·186	·117	·097	·044	·020	·010		
29·725 and 29·749						·009	·050	·105	·175	·177	·049	·068	·042	·067	·124	·191	·154	·078	·081	·035	·014			
29·700 and 29·724						·003	·023	·069	·097	·130	·114	·107	·062	·098	·198	·148	·144	·032	·032	·016	·003	·003		
29·675 and 29·699							·010	·049	·032	·111	·154	·104	·123	·104	·164	·130	·062	·019	·019	·009				
29·650 and 29·674								·023	·019	·025	·141	·139	·159	·138	·121	·108	·046	·013	·013	·003				
29·625 and 29·649								·003	·003	·057	·134	·159	·166	·205	·111	·037	·046	·016		·003	·003			
29·600 and 29·624									·007	·022	·134	·094	·149	·138	·064	·015	·010	·019	·006					
29·575 and 29·599										·022	·065	·065	·097	·095	·030	·009	·016	·010	·003					
29·550 and 29·574									·003	·009	·062	·055	·042	·055	·013	·006	·003	·006						
29·525 and 29·549										·009	·023	·055	·055	·018	·003			·006						
29·500 and 29·524										·006	·016	·036	·019	·021	·003									
29·475 and 29·499											·007	·029	·006	·006										
29·450 and 29·474											·003	·003												
29·425 and 29·449											·003	·003												
29·400 and 29·424											·003													
Fortnightly means	29·942	29·932	29·920	29·893	29·874	29·847	29·813	29·782	29·773	29·732	29·657	29·647	29·646	29·652	29·696	29·727	29·749	29·790	29·813	29·843	29·879	29·920	29·926	29·947

45. With these numbers have been constructed the series of stepped double pyramids in fig. 207, in which the horizontal dimension of each elemental rectangle is equal, on the scale shown at the upper margin of the curve form, to the corresponding number in the table. The horizontal lines crossing the pyramids near the middle, mark the mean barometric pressures of the several fortnights. The closing up of these pyramids vertically, and expansion laterally, implies a state of relative constancy and stability of pressure, and their elongation vertically a state of greater variability. That of the first fortnight in June stands out prominently, as one in the latter category, both in the relative fewness of occurrences near the mean pressure of the fortnight, and in the wide departures from the mean, both in the direction of excessive and defective pressures. In respect of the first of these characteristics the succeeding fortnight holds the next place in the same category,

but in respect of the occurrence of large excursions from the mean, especially in the direction of defective pressures, the last fortnight in September takes precedence of it. The first and last of these periods are near the beginning and end of the monsoon, when the general state of the weather is more disturbed than at any other season, and the northward and southward normal wind currents are contending against each other for predominance, and when storms, accompanied by thunder and lightning, almost exclusively occur. The course of the line joining the middle points of the mean lines in the successive pyramids of course traces out roughly the annual variation of barometric pressure.

46. *Abnormals.*—We have now obtained, from records extending, in each case, over 25 years or more, values (1) of the mean annual barometric pressure, and (2) of the annual inequality for each day of the year: the sum of the two for any given day of the year is the most probable value of the mean barometric pressure for that day, and may be called the normal for the day. We might add further the inequality for a given hour of the mean diurnal variation for that day, and should then obtain the most probable value of the mean barometric pressure for the particular hour of the particular day of the year: this might be called the normal for the particular hour of the particular day. The actual values would, however, in general be somewhat greater or less than the normal values, because the normals are averages from long periods, whilst the actual values are affected by any casual disturbances which may be in operation at the time or period of observation: the excess or defect of the actual pressure, as compared with the normal pressure, we call the abnormal pressure of the time or period, and hourly, daily, monthly, or annual abnormals are the algebraical excesses above the corresponding hourly, daily, monthly, or annual normals.

47. *Probable error.*—To explain the object and reason for our next procedure, let us first look for analogous phenomena to our normals and abnormals in the observed positions of a planet in its orbit about the sun, the observer looking down upon the plane of the orbit. If the period of the planet were divided into a great number of equal intervals, and the positions were observed at the beginning of each interval, it would be found at the end of one period that the track of the planet deviated sensibly, and apparently irregularly, from the ellipse which, under the theory of gravitation, it would describe exactly if the sun and the one planet were the only bodies in the universe; but if the observations were repeated through a large number of complete revolutions, and the *average* position of the planet were traced, it would be found to correspond very closely with the theoretical ellipse: our normals correspond then to these average positions of the planet, and our abnormals to the deviations, at the same phase of the period, of individually observed positions from the average.

Now if the theory of gravitation had gone no further than to point out the form of orbit the planet would describe under the mutual attraction between itself and the sun, it would be in accordance with the present practice of physicists to estimate the completeness of the theory by the smallness of the probable error of observation. It is at the same time well known that if the deviations from the theoretical position succeed each other in any systematic way—as, for instance, by being all in excess for a time, and

then all in defect for an equal time, and so on, or by being more frequently on one side of the theoretical position than on the other—the application of the method of the theory of errors of observation will yield a probable error which will be too great, regarded as a probable error of observation simply, but will approach nearer and nearer to the true probable error of observation as the theory is improved. Such an improvement in the theory of the motion of the planet would result from taking account of the perturbations caused by the attractions of the other planets. And here we would remark that just as the deviations of position, which are the aggregates of the perturbations caused by all the other planets, are complex phenomena, whilst the principal elliptic motion of the planet is a simple one, so it is not unlikely that the abnormals of meteorological phenomena, regarded collectively, are due to much more complex causes than the normals; and just as it would have been appropriate and suggestive, apart from any knowledge of the theory of gravitation, to separate the motions of the planet into the normal—corresponding to the average positions observed—and the abnormal—corresponding to the individual departures from the normal positions—for independent consideration, so here it is appropriate, apart from any knowledge of explanatory physical causes, to adopt the same course. Such a separation is convenient also in permitting the comparison of normal phenomena of one kind with normal of another, abnormal with abnormal, and similarly with respect to the comparison of like phenomena at different places.

48. The formula by which the probable errors are calculated is

$$r = \sqrt{\frac{\Sigma(\alpha^2)}{n-1}} \times 0{\cdot}674489 = 0{\cdot}674489\, e,$$

where $\Sigma(\alpha^2)$ is the sum of the squares of the several abnormals, n is the number of the abormals, and $e = \sqrt{\frac{\Sigma(\alpha^2)}{n-1}}$. It has been applied to the daily abnormals of barometric pressure for the three years 1868 to 1870, treating the abnormals of the same fortnight in each of the three years as one group. The results for the several fortnights are shown in the following table.

TABLE 12.

Month	January.		February.		March.		April.		May.		June.	
Fortnight	1	2	1	2	1	2	1	2	1	2	1	2
$\Sigma(\alpha^2)$	·129512	·067780	·087194	·055037	·049626	·073068	·097430	·061652	·094255	·058571	·333748	·429720
n	36	40	35	34	37	40	37	39	38	37	39	39
Probable error r	·041	·028	·034	·028	·025	·029	·035	·027	·034	·027	·063	·071

TABLE 12—*continued.*

Month	July.		August.		September.		October.		November.		December.	
Fortnight	1	2	1	2	1	2	1	2	1	2	1	2
$\Sigma(\alpha^2)$	·147343	·137907	·087113	·129704	·187566	·309117	·038114	·150650	·085589	·087930	·123470	·093324
n	39	41	36	40	39	39	39	38	37	39	39	40
Probable error r	·042	·040	·034	·039	·047	·061	·022	·043	·033	·032	·033	·033

Here and hereafter in this paper probable error must be understood, not in its strict sense, but as measuring the degree of fulness with which the normals represent the total phenomena observed: if this representation were complete, the probable error would become the true one, and it increases in magnitude as the frequency and extent of disturbance increases. In accordance with this idea, combined with the rule of the theory of probable errors of observation, and noting, by inspection of the pyramids of fig. 207, that the distribution of pressures above and below the mean pressure is decidedly unsymmetrical, the numbers in Table 12 must be interpreted as indicating that, in the several fortnights, *more* than half the number of mean daily pressures lie within a range of the normal pressure of the day represented by the respective numbers, the range being taken above and below the normal. Or an equivalent interpretation is that if, for example, 24 hourly observations of barometric pressure be taken on any day in the first fortnight of January, their mean value will be more likely to differ from the normal pressure of the same day of the month by less than ·041 inch than by a greater quantity. The number ·041 inch is thus a measure of the degree of approximation to the normal that a single day's observations may be expected to afford. It will be noticed that, as we found by the method previously described (paragraph 45), the first and second fortnights in June, and the last in September, are the most disturbed.

49. *Unequal magnitude and frequency of positive and negative abnormals.*—The unsymmetrical distribution of pressures above and below the normal pressure is deemed worthy of a closer exposition than is afforded by an inspection of the pyramids of fig. 207. We have accordingly counted the number of occurrences of daily abnormals of values lying between 0·00 and +0·02 inch, between +0·02 and +0·04 inch, between +0·04 and +0·06, and so on, and similarly between 0·00 and −0·02, inch, &c. &c. in the years 1868 to 1872. The numbers are shown in the next table, and are curved in fig. 207*a*, from which it is seen that abnormals between 0·00 and +0·04 are more frequent than any others, and that those of positive sign are much more numerous than those of negative sign. This is, of course, a necessary concomitant of the fact that, on the whole, the depressions below the normal are of larger extent than the elevations above it.

TABLE 13.

Abnormals lying between limits.	Numbers.	Abnormals lying between limits.	Numbers.	Abnormals lying between limits.	Numbers.
+·180 and +·199	1	+·020 and +·039	242	−·120 and −·139	14
+·160 and +·179	2	+·000 and +·019	241	−·140 and −·159	11
+·140 and +·159	4	−·001 and −·019*	206	−·160 and −·179	4
+·120 and +·139	11	−·020 and −·039	160	−·180 and −·199	3
+·100 and +·119	25	−·040 and −·059	124	−·200 and −·219	2
+·080 and +·099	50	−·060 and −·079	91	−·220 and −·239	3
+·060 and +·079	98	−·080 and −·099	36	−·240 and ·259	1
+·040 and +·059	163	−·100 and −·119	25		

* The limits in this case having been inadvertently chosen with an interval of 0·19 inch instead of ·020 inch, the number should be increased by about one nineteenth to make it comparable with the rest; it then becomes 217. The general distribution of abnormals is not materially affected by this error.

Dry and Wet Bulb Thermometers.—Temperature and Humidity of the Air.

50. In Dr. Buist's report for 1844 he expresses a doubt as to the trustworthiness of the observations of temperature of the air made in that year; we shall therefore pay no regard to them here, but begin with the year 1847.

51. *Description.*—The dry and wet bulb thermometers used from 1847 to 1872 were all mercurial thermometers by Newman, of London, and were without any distinguishing numbers; the bulbs were nearly spherical in form, and the frames upon which the scales were divided were all of brass. The records mention the breakage of a dry bulb thermometer on the 31st March 1852, and of wet bulb thermometers on the 2nd November 1854 and 21st November 1863; but as the dry bulb thermometer in use in September 1865 differs in several points from that which was substituted for the broken one in 1852, it is certain that at least one other substitution must have been made between the dates named. The observations show somewhat abrupt changes about November 1864 and July 1865, with a persistently high temperature during the intervening period; these changes may possibly indicate unrecorded changes of instrument, but as no errors are recorded of the thermometers used after 31st March 1852, and until September 1865, no corrections can with safety be applied to the observed readings.

The following statement exhibits all the important points on record in regard to the dimensions, period of use, &c. of the several dry and wet bulb thermometers.

Table 14.

	Thermometer.	Date from which used.	Scale divided to.	Range.	Average length of 1°.	Diameter of Bulb.		Height of Bulb above Ground.	Date from which disused.
						Vertical.	Horizontal.		
			Fahrenheit.		Inch.	Inch.	Inch.	Feet.	
Dry Bulb.	A	1847. 1st January	0°·2	20° to 110°	0·145	0·67	0·40	3	1852. 31st March.
	B	1852. 1st April		0° to 110°	0·15	0·6	0·4	5	Not recorded.
	C	Not recorded	0°·2	5° to 115°	0·117	0·55		4 till 20th Jan. 1866, afterwards 4½	Still in use in 1875.
Wet Bulb.	D	1847. 1st January	1°		0·04	0·5		3	1854. 2nd November.
	E	1854. 2nd November	No details recorded.					2½	1863. 21st November.
	F	1863. 21st November	1°	10° to 133°	0·044	0·53		2½ till 20th Jan. 1866, afterwards 4½	Still in use in 1875.

The bulb of the thermometer A was always freely exposed to the air; the thermometer B, also C, till the 5th December 1865, was enclosed in a wooden box frame with a glass window in front, and with holes to admit the air at each side of the bulb; but on the day named the frame of the thermometer C was removed, and its bulb has since been freely exposed.

The bulbs of the wet thermometers have always been covered with muslin, and kept moistened by the capillary action between a small vessel of water, near the thermometer bulb, and a bundle of fine cotton yarn, which dipped into the water, and passed loosely round the thermometer stem just above the bulb.

52. *Errors of thermometers.*—The results of comparisons of the dry and wet bulb thermometers with standard thermometers are shown in the following table:—

TABLE 15.

THERMOMETER A.		THERMOMETER C.		THERMOMETER F.	
Limits.	Correction required.	Limits.	Correction required.	Limits.	Correction required.
°	°	°	°	°	°
45 to 55	− 0·4	50 to 61·9	− 0·6	44 to 52·9	0·0
55 to 65	− 0·7	62 to 87·9	− 0·7	53 to 53·9	− 0·1
65 to 75	− 0·4	88 and above	− 1·0	54 to 55·9	− 0·2
75 to 85	+ 0·1			56 to 56·9	− 0·3
85 to 95	0·0			57 to 57·9	− 0·4
95 to 105	− 0·2			58 to 58·9	− 0·5
				59 to 66·9	− 0·6
				67 to 76·9	− 0·7
				77 to 87·9	− 0·8
				88 and above	− 1·0
Comparisons made by Professor Orlebar in 1846 with a thermometer called by him "the Standard."		Comparisons made by Mr. C. Chambers indirectly with a "Kew Standard" in December 1866; verified by Mr. F. Chambers in 1875 by repetition of determination of freezing points			

The corrections shown above for thermometers C and F have been applied to every individual observation of air temperature and temperature of evaporation respectively that has been made since the 1st January 1866, but to the observations taken before that date no corrections have been applied. The dry and wet bulb thermometers have always been read between five and seven minutes after the hour of Bombay civil time. From 1847 to 1850 the thermometers were placed in a shed, at a distance of about 18 feet from the south-west corner of the Magnetic Observatory. This shed was six feet high to the crutch of the roof, and six feet square inside; the roof was of bamboo rafters, thatched with leaves of the cocoa-nut tree; the sides of the shed were protected from the sun's rays by date leaf mats, which during the sunny part of the day were shifted from time to time by the observer. Within the shed, near the north-east corner, was sunk a wooden post, three feet high from the ground, carrying a horizontal board, 14 inches square, which was padded with cotton and covered

over the cotton with a bright tin plate; the purpose of this tinned board, above and near which were the bulbs of the dry and wet thermometers, was to cut off radiation from the ground. The dry bulb thermometer was suspended from the roof, and the wet bulb was attached to a stand which rested on the tinned board.

53. *Situation.*—From 1851 to the present time the thermometers have been placed in a similar but more roomy shed 30 feet to the south-eastward of the Magnetic Observatory. It has a similar roof to the old shed, and open sides supplied with shutter frames, which are covered with bamboo matting, and swing on hooks vertically; the shutters are propped open at an angle of about 40° from the vertical; the floor, which is of red earth, is raised a few inches to prevent any flow of rain into the inside of the shed during the wet season, and the north-eastern and south-western corners of the shed are protected by strips of bamboo matting against the ingress of direct rays of the sun in the morning and evening; the south-eastern corner is sufficiently protected by the overhanging branches of a mangoe tree. The shed is 12 feet square, and 9 and 14 feet high to the crutch and to the highest point of the roof respectively. Till 2 p.m. of the 20th January 1866 the dry bulb thermometer was suspended by a hook from the roof, with its bulb at a height of four feet above the middle of the floor; and beneath it was a small light table, upon which stood the wet bulb thermometer, with its bulb two inches above the top of the table, and $2\frac{1}{2}$ feet from the ground. The table which was brought into use with the new shed in 1851 was intended to serve as a substitute for the tinned board. For more effectually cutting off any direct breeze from the wet bulb thermometer, and for the better protection of other thermometers in constant use from solar radiation, they were, early in January 1866, mounted on light wooden rods inside an open cage with venetian sides and depressed venetian bottom; the cage was supported by four corner posts which entered the ground, leaving its open bottom at a height of three feet, and the bulbs of thermometers $4\frac{1}{2}$ feet from the soil; the dimensions of the cage are three feet square and five feet high, and the roof is completely closed; the position occupied by it is the middle of the thermometer shed.

54. *Mean temperature of the air.*—The following table shows the monthly mean temperature for each month of the 26 years from 1847 to 1872. The values are derived for the first five months of 1847 from observations taken at the even hours of the day only, and the rest from hourly observations. On Sundays and a few holidays in each year no observations were taken.

TABLE 16.

MONTHLY and ANNUAL MEAN VALUES of the TEMPERATURE of the AIR for the 26 years from 1847 to 1872.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
YEAR.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Means.	Excess of individual annual Means above the Mean for the 26 years.	Greatest monthly Mean *minus* least monthly Mean.
1847	75°·2	73°·7	79°·4	82°·1	83°·9	81°·0	80°·4	79°·8	78°·9	82°·1	75°·9	75°·5	79°·0	− 0°·8	10°·2
1848	75·5	75·1	78·7	83·1	84·6	81·4	81·1	80·2	81·0	80·9	79·3	76·6	79·8	0·0	9·5
1849	73·3	75·8	79·2	82·1	85·2	81·3	80·1	80·1	78·8	81·2	81·3	76·5	79·6	− 0·2	11·9
1850	72·4	75·1	79·3	82·0	84·4	83·8	81·7	81·0	80·7	83·0	79·3	75·8	79·9	+ 0·1	12·9
1851	72·2	75·5	79·8	83·3	84·6	82·5	80·1	79·9	80·4	81·5	79·4	75·0	79·5	− 0·3	12·4
1852	71·9	75·8	80·1	83·2	86·3	83·9	82·0	80·3	80·6	82·1	80·2	75·7	80·2	+ 0·4	14·4
1853	71·6	76·4	81·6	83·5	86·9	84·0	80·5	80·8	80·7	82·0	80·6	76·9	80·5	+ 0·7	15·3
1854	75·8	75·0	80·3	83·9	86·9	84·2	80·4	81·3	80·9	81·7	79·8	77·3	80·6	+ 0·8	11·9
1855	74·7	77·0	79·2	82·0	86·0	83·8	82·0	82·1	81·0	82·6	80·5	77·7	80·7	+ 0·9	11·3
1856	76·4	77·1	81·5	84·7	86·1	83·0	81·0	80·6	80·1	80·9	79·0	75·4	80·5	+ 0·7	10·7
1857	74·7	77·7	81·8	83·1	86·1	83·4	82·1	79·3	79·0	80·5	77·4	73·9	79·9	+ 0·1	12·2
1858	73·3	75·2	79·9	84·4	86·2	83·8	81·2	80·5	80·5	81·2	79·1	75·5	80·1	+ 0·3	12·9
1859	74·6	76·6	79·3	84·5	85·2	84·1	82·5	80·4	79·9	80·3	80·5	74·2	80·2	+ 0·4	11·0
1860	72·3	75·5	79·2	81·6	85·0	83·9	81·0	80·8	81·2	83·2	78·7	77·5	80·0	+ 0·2	12·7
1861	74·8	75·7	77·9	82·8	85·2	82·7	80·6	79·4	80·4	80·5	76·9	74·4	79·3	− 0·5	10·8
1862	72·9	76·9	78·4	83·0	85·8	83·6	83·1	81·6	81·4	82·4	81·5	76·6	80·6	+ 0·8	12·9
1863	74·3	76·1	79·0	83·7	86·0	82·5	80·8	79·5	79·5	81·6	78·6	75·7	79·8	0·0	11·7
1864	71·3	75·0	78·0	81·3	84·1	84·4	82·0	80·3	81·2	81·9	80·6	78·3	79·9	+ 0·1	13·1
1865	77·3	77·0	79·5	84·9	87·6	85·4	82·8	80·3	81·2	80·9	78·7	77·0	81·0	+ 1·2	10·6
1866	72·9	71·8	77·2	79·2	82·7	82·7	79·6	79·2	80·0	81·4	77·8	75·4	78·3	− 1·5	10·9
1867	74·2	73·1	76·9	80·6	84·7	84·7	80·5	79·7	79·6	79·9	76·6	74·9	78·8	− 1·0	11·6
1868	72·9	74·8	76·6	81·6	84·5	83·2	80·2	79·6	80·0	81·3	78·8	75·7	79·1	− 0·7	11·6
1869	75·3	75·7	77·9	82·0	84·1	83·9	82·1	80·8	79·8	80·2	79·1	77·5	79·9	+ 0·1	8·8
1870	73·6	75·6	78·8	81·2	83·7	82·7	79·4	79·4	79·3	79·5	79·0	76·3	79·0	− 0·8	10·1
1871	74·9	76·3	79·3	83·5	85·6	83·4	80·7	79·1	79·4	81·2	80·4	77·4	80·1	+ 0·3	10·7
1872	71·7	73·5	78·6	81·6	84·1	82·9	80·1	79·2	79·8	79·7	78·2	77·6	78·9	− 0·9	12·4
Means. Of 26 years	73·8	75·5	79·1	82·6	85·2	83·3	81·1	80·2	80·2	81·3	79·1	76·2	79·8		11·4
Means. 1848 to 1851	73·3	75·4	79·2	82·6	84·7	82·2	80·7	80·3	80·2	81·6	79·8	76·0	79·7		11·4
Means. 1853 to 1865	74·2	76·2	79·7	83·3	85·9	83·8	81·5	80·5	80·5	81·5	79·4	76·2	80·2		11·7
Means. 1866 to 1872	73·6	74·4	77·9	81·4	84·2	83·3	80·4	79·6	79·7	80·5	78·6	76·4	79·2		10·6

The mean temperature shown for the 26 years is 79°·8.

55. *Exposure.*—Omitting the year 1847, when, for five months, observations only at intervals of two hours were taken, and 1852, when a change of thermometer is known to have taken place, we divide the remaining years into groups as follows: I., 1848 to 1851; II., 1853 to 1865; and III., 1866 to 1872. The differences in columns Nos. 15 and 16 show both a higher absolute temperature and a larger range for groups I. and II. than for group III., but it is not improbable that the greater part of the excess range and some part of the excess temperature are due to difference in the manner of exposing the thermometer with reference to surrounding objects, whilst other parts of the latter excess may be uneliminated error of the instrument, not now ascertainable, and real difference of mean temperature in

the several periods. During the first and second periods the thermometer was screened from radiation from the ground, but not from radiation from the partially matted sides and roof of the shed, which appears throughout to have been covered with several layers of large dried leaves. During the third period the protection from radiation was extended to all sides, the venetian boarding of the thermometer cage affording it on the four sides and below, and the closed wooden roof of it at the top; and between the roof of the cage and the shed was a freely ventilated space of four feet depth; the cage itself is also completely screened by the roof and opened shutter frames of the shed from the direct rays of the sun. The effects upon the thermometer of radiation from surrounding bodies will depend upon their nearness and excess or defect of temperature as compared with that of the thermometer, and the first effect we should look for in the present case would be an excess of temperature in the day hours, when the sun was shining upon the roof of the shed, and a corresponding but less considerable defect during the night hours; the total effect would be to increase the mean temperature of the day when the radiation increased, and this in greater degree during the comparatively dry and cloudless months October to May, than during the monsoon months June to September, cloudiness being presumed to be more influential than favourable position of the sun. Thus we should expect both the mean temperature and diurnal range of temperature to be least for the third period, and the difference between the mean temperature of the dry and wet months of the year to be also less for the third than for the two other periods. The mean diurnal range for the third period is 8°·8; for the first and second periods it is 9°·8 and 10°·0 respectively. The mean temperature for the dry and wet months of the several periods are shown in the following table:—

TABLE 17.

Periods.	October to May.		June to September.		Excess of October to May difference above June to September difference.
	Mean Temperature.	Excess above period 1866 to 1872.	Mean Temperature.	Excess above period 1866 to 1872.	
1848 to 1851	79°·1	+0°·7	80°·8	0°·0	+0°·7
1853 to 1865	79·5	+1·1	81·6	+0·8	+0·3
1866 to 1872	78·4		80·8		

from which it appears that, assuming the third period to represent one of standard exposure, the dry months' mean of the first period must be regarded as affected by radiation more than the wet months' mean by 0°·7; and in the second period this greater affection is 0°·3.

56. Since the 20th August 1874 a thermometer by Newman has been suspended in the thermometer shed outside the cage, so that its exposure should be approximately comparable with that of the period from 1853 to 1865, and simultaneous readings have been taken of it and of the thermometer within the cage at the hours (6 a.m.) of minimum and (2 p.m.) of maximum temperature. The following table shows the mean readings for several months, corrected in both cases for index errors of the instrument:—

TABLE 18.

Year and Month.	At 6 A.M. Thermometer. Inside (Of Cage.)	At 6 A.M. Thermometer. Outside (Of Cage.)	Excess of outside Thermometer.	At 2 P.M. Thermometer. Inside (Of Cage.)	At 2 P.M. Thermometer. Outside (Of Cage.)	Excess of outside Thermometer.	Range. Inside (Of Cage.)	Range. Outside (Of Cage.)	Excess of Outside.
1874, August -	77°·1	77°·2	+0°·1	83°·1	83°·8	+0°·7	6°·0	6°·6	+0°·6
„ Sept. -	77·2	77·2	+0·1	82·5	83·0	+0·5	5·3	5·8	+0·5
„ October -	76·4	76·3	−0·1	86·2	87·1	+0·9	9·8	10·8	+1·0
„ Nov. -	73·0	73·1	+0·1	84·6	85·3	+0·7	11·6	12·2	+0·6
„ December	71·1	71·2	+0·1	83·0	84·0	+1·0	11·9	12·8	+0·9
1875, January -	67·3	67·2	−0·1	79·3	80·1	+0·8	12·0	12·9	+0·9

Here again the range is greater outside the cage, though the excess is less, as might be expected, than when, as in 1853 to 1865, the outside thermometer was fully exposed to the whole of the roof of the shed, a condition which the presence of the cage renders impracticable in these experiments. Observing that the difference of range is almost entirely due to the excess of the 2 p.m. observation outside over inside, the 6 a.m. observations being nearly identical within and without the cage both in the dry and wet season, we may now arrive at the same result as to the effect of exposure to the roof, by a comparison of the mean temperatures for the whole day and for 6 a.m. in the several periods. The excess of the mean for the day above the mean of all the 6 a.m. observations in the first period is 4°·4, in the second period 4°·3, and in the third period 3°·8; thus, again taking the third period as representing a standard exposure, we find that the mean temperature of the 1848 to 1851 period is too high in consequence of radiation by 0°·6, and the mean temperature of the period 1853 to 1865 too high by 0°·5. These results are for the whole year, but the cloudy months July and August yield corresponding excesses of 0°·2 and 0°·3 only, the respective daily means being in excess of the 6 a.m. means by 1°·9, 2°·0, and 1°·7, in the first, second, and third periods. The agreement of the observations at 6 a.m., within and without the cage, is confirmatory of the supposition made above, that the effect of radiation from the roof would be less considerable at night than in the daytime; indeed it appears to be almost insensible about sunrise, a time when the roof can scarcely have become sensibly warmed. As the sun passes through the zenith of Bombay in May, and in January is about 40° from it at noon, this circumstance will, notwithstanding any difference of dryness or cloudiness, probably determine that the quantity of heat communicated to the roof of the shed in the former month will be greater than in the latter, and thus the daily mean temperature will be more raised by radiation from the roof in May than in January; hence the greater annual range—May being the month of highest and January that of lowest temperature—when the thermometer is most exposed to the roof, *i.e.* in the first and second periods, as compared with the third.

57. The figures that we have now brought forward afford unmistakeable evidence that the general conception of the effect of radiation that we have laid down has something of truth in it, though, as will presently appear, it by no means embodies the whole truth. It would not be inconsistent with that conception to suppose that if the ratio of the rise of temperatures from 6 a.m. to some one other hour under two different exposures were given, it would hold good for all the other hours also; in other words, that the law, though not the extent, of the diurnal variation of temperature under the two exposures might be the same. An examination of the mean temperatures at the different hours in the several periods shows that this is far from being the case.

TABLE 19.

MEAN TEMPERATURE OF AIR.

Group.	Period.	BOMBAY CIVIL HOURS.																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
I.	1848 to 1851 -	76·8	76·6	76·3	76·0	75·8	75·4	75·3	77·0	79·8	82·1	83·6	84·6	85·1	85·0	84·5	83·6	82·9	81·5	80·0	79·4	78·9	78·3	77·6	77·2
II.	1853 to 1865 -	77·5	77·2	76·8	76·6	76·3	76·0	75·9	77·0	79·0	80·8	82·4	83·7	84·9	85·6	85·9	85·7	84·9	83·1	81·0	80·0	79·4	78·8	78·2	77·8
III.	1866 to 1872 -	77·0	76·7	76·4	76·1	75·8	75·6	75·4	76·2	77·8	79·2	80·6	81·9	83·0	83·9	84·2	84·1	83·4	81·9	80·2	79·3	78·8	78·3	77·7	77·3
I. minus III. -	-	−·2	−·1	−·1	−·1	0·0	−·2	−·1	+·8	+2·0	+2·9	+3·0	+2·7	+2·1	+1·1	+0·3	−·6	−·5	−·4	−·2	+·1	+·1	0·0	−·1	−·1
II. minus III. -	-	+·5	+·5	+·4	+·5	+·5	+·4	+·5	+·8	+1·2	+1·6	+1·8	+1·8	+1·9	+1·7	+1·7	+1·6	+1·5	+1·2	+·8	+·7	+·6	+·5	+·5	+·5

The approach to constancy in the two sets of differences, from about sunset to sunrise, shows that the movements of the thermometer are practically the same during the night hours, under the three different forms of exposure; and the constancy of the differences in the last line, from 10 to 14 hours, shows that the thermometer behaves in the same way, at that part of the day, both within and without the cage, whilst the excess rise between sunrise and 10 hours, and the excess fall between 14 hours and sunset, are, as shown by the differences in the last line, most rapid about the times when the absolute rise and fall of temperature are most rapid; these are the hours therefore at which insufficient protection of the thermometer most affects the character of the derived diurnal variation of temperature. In the daytime the hourly excesses of group I. above group III. rapidly increase from about sunrise to $9\frac{1}{2}$ hours, and then gradually diminish till sunset, the diminution being most rapid from 12 to 15 hours. This movement is of a character so unlike the variation of absolute temperature during the daytime, as shown (say) by the line of figures under group III., that the combination of the observations of group I. with the later periods is inadmissible; but so also is the combination of group II. with group III., on account of the considerably greater values of the excesses of temperature in the day hours as compared with those of the night hours. We shall therefore confine our inquiry into periodical variations to the observations of group III. for the period from 1866 to 1872. Not that we by any means claim that the observations of the 1866 to 1872 period are absolutely free from radiation effects, nor that we are unaware that every additional screen used as a protection against radiation is itself liable to be somewhat late in following the changes of temperature of the air, and

thus to retard the occurrence of corresponding phases, and contract the range of variation; but that in this group radiation from near bodies is least influential and the circulation yet satisfactorily unimpeded.

58. There is, however, yet great need of special experimental investigation of the conditions of exposure in a tropical climate best calculated to yield comparable records; and as a further contribution towards it, we may compare the observations taken in the thermograph shed with those taken in the thermometer shed in the years 1873 and 1874. The thermograph shed has a skeleton framework of teak-wood, 22 feet by 18 feet, with roof of teak-wood covered with thick felt and canvas, and painted white; the sides are constructed to appear like venetian boarding on a large scale, and are made of sheets of zinc enclosing thick felt, and painted white. Within the shed are erected a thermometer cage like that described in paragraph 53, and nearly adjoining it the thermograph room, in which the recording apparatus is placed. The roof of the shed is six feet higher than that of the cage. The thermometer is placed in the cage with its bulb 10 feet from the ground, and is read four minutes before the thermometer in the thermometer shed, *i.e.* at two minutes past the full hour. The ground level is a little higher than that under the thermometer shed.

TABLE 20.

COMPARISON of MEAN READINGS (corrected for index errors) of THERMOMETERS in THERMOMETER SHED, and in THERMOGRAPH SHED, in the Years 1873 and 1874.

Hour.	1873.			1874.		
	In Thermometer Shed.	In Thermograph Shed.	Excess in Thermograph Shed.	In Thermometer Shed.	In Thermograph Shed.	Excess in Thermograph Shed.
6 a.m. -	75·1	75·3	+0·2	74·6	74·8	+0·2
10 a.m. -	80·2	80·7	+0·5	79·5	80·0	+0·5
2 p.m. -	84·0	83·2	−0·8	83·3	82·6	−0·7
4 p.m. -	83·2	82·2	−1·0	82·7	81·6	−1·1
10 p.m. -	77·4	77·6	+0·2	76·8	77·0	+0·2
Means - -	80·0	79·8	−0·2	79·4	79·2	−0·2
Range from 6a.m.to 2p.m.	8·9	7·9	−1·0	8·7	7·8	−0·9

The range in both years is about one degree less in the thermograph shed than in the thermometer shed, and the rapidity of rise of temperature between 6 a.m. and 10 a.m., and of fall between 2 p.m. and 4 p.m., is greater in the same case; in which also the rise of 10 a.m. to 2 p.m., and fall from 4 p.m. to 10 p.m., are slower than in the other.

The mean temperature of the wet and cloudy months, June to September, is in the thermograph shed within a tenth of a degree of that in the thermometer shed, whilst the mean temperature of the remaining eight months is 0°·3 lower in the thermograph shed

than in the thermometer shed. From this fact, as well as from the smaller diurnal range,—and notwithstanding that both may be partly due to difference of elevation of the thermometers above the ground,—we infer that the thermometer in the thermograph shed is even more effectually protected from radiation than that in the thermometer shed; and it probably owes this advantage partly to the greater dimensions of the shed, and consequent greater distance of its sides from the thermometer, and partly to the material of which the sides, which extend upward two feet higher than the cage, are made, a material which, being a good conductor, gives up its heat readily to the air which comes in contact with it, and is at the same time a worse radiator than the leaf matting of the thermometer shed.

In our remarks upon the diurnal variations we have supposed that, neglecting the consideration of difference of exposure, they would have sensibly the same character in one period as another; in strictness this is only allowable when the periods are of great length, and even then we must suppose that there is no secular change of the diurnal variation. Under present circumstances—of ignorance on the latter point, and limitation of means on the former—we nevertheless regard our procedure as legitimate.

59. We may mention too, as evidence of the unsuitableness for tropical climates of revolving thermometer stands, such as are commonly used in England, that the mean diurnal range, observed by means of maximum and minimum thermometers placed in such a stand, for the years 1856 to 1865 was 11°·9; whilst the mean range of the same or similar thermometers, placed in the cage of the thermometer shed, for the years 1866 to 1873 was 9°·9, showing a difference of 2°·0 as the effect of radiation from the stand. The thermometers rested against a vertical board, which was screened from sunshine by a double inclined board behind and above it, and air was free to circulate between the two boards of the double shade, and between the shade and the vertical board. The stand was turned on a vertical axis, as the day advanced, so as to keep the vertical board always in the shade.

60. *Five-year means.*—The mean temperatures, affected by difference of exposure, for the five-year periods adopted by the Vienna Congress are as follows: 1851 to 1855, 80°·3; 1856 to 1860, 80°·1; 1861 to 1865, 80°·1; and 1866 to 1870, 79°·0.

The mean temperature for the seven years 1866 to 1872 is 79°·2.

61. *Annual variation of temperature.*—The same process was used for finding the annual variation of temperature as for the annual variation of barometric pressure; viz., the mean temperature was calculated for each day in the year: first for each year, and then for the average of the seven years 1866 to 1872. The numbers were arranged in line, and six smoothing operations performed, and the value adopted as the normal temperature of each day was the mean of its own and of the seven preceding and seven following sixth smoothed means.

The three following Tables are similar to Tables 2, 3, and 4 of barometric pressure.

TABLE 21.

SHOWING the MEAN TEMPERATURE of each Day of the Year, derived from the Observations of the Years 1866 to 1872.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	December.
1	[74·2]	73·2	76·9	79·6	83·3	85·6	82·8	79·9	78·7	80·0	78·9	77·7
2	74·8	73·5	76·3	78·9	83·4	85·9	82·6	79·5	79·3	80·0	79·5	78·5
3	74·8	73·2	76·4	79·7	83·8	86·0	82·0	79·3	79·7	80·5	80·5	78·3
4	73·9	73·7	75·7	80·2	83·7	85·2	81·2	80·2	79·5	79·5	80·2	78·5
5	72·3	71·8	76·0	80·5	84·0	85·2	81·4	80·3	79·7	79·9	79·4	78·0
6	71·8	72·0	75·7	81·1	84·0	85·6	80·8	80·4	80·1	80·8	79·9	78·4
7	73·1	72·1	77·1	80·4	83·5	84·7	81·6	79·6	80·2	80·1	79·3	78·3
8	72·7	73·4	76·3	80·8	84·1	84·6	82·2	79·3	79·8	79·8	79·7	77·8
9	72·4	73·0	76·0	80·4	83·6	84·1	82·5	79·0	80·1	81·0	79·1	77·4
10	74·0	74·9	76·3	81·2	83·9	83·9	82·9	78·6	80·1	80·6	79·4	77·0
11	73·6	74·6	77·1	80·7	84·0	84·4	80·6	79·2	80·5	80·7	79·0	76·7
12	73·9	72·7	77·3	81·1	83·8	83·7	79·5	80·1	79·5	81·2	78·4	76·5
13	73·5	74·1	77·4	81·2	84·1	84·5	78·8	79·3	79·8	80·1	77·4	76·4
14	75·3	73·9	78·3	81·6	83·9	83·9	78·9	79·6	80·0	80·9	78·0	76·0
15	74·4	75·1	78·0	81·7	83·8	83·1	79·4	79·1	80·4	80·5	78·3	76·5
16	73·7	75·1	77·4	81·8	83·8	82·2	79·0	79·8	79·7	80·4	79·0	77·1
17	72·3	76·0	77·6	81·7	83·5	82·6	79·8	79·4	79·9	81·3	79·5	75·9
18	73·0	75·5	78·6	81·3	83·9	82·1	79·0	80·2	79·9	81·6	78·4	76·3
19	74·1	74·3	78·2	82·2	84·1	82·1	79·1	79·9	80·0	81·1	78·1	76·2
20	73·7	73·4	78·7	81·7	84·3	82·2	79·4	79·0	79·4	81·3	78·3	76·8
21	73·7	75·0	78·9	81·9	84·1	81·6	78·6	79·2	79·0	81·1	78·4	75·7
22	73·3	75·3	79·3	82·5	84·4	81·5	79·8	79·6	79·9	81·5	78·2	75·6
23	74·0	75·1	79·5	82·3	84·5	81·9	79·4	79·6	79·2	81·2	77·9	74·6
24	73·1	76·6	79·4	83·2	[84·6]	81·0	80·0	80·2	79·5	80·8	77·7	75·5
25	73·4	75·6	78·9	82·3	84·8	81·5	80·1	80·2	79·6	79·7	77·8	[75·4]
26	73·6	77·8	78·8	82·0	84·7	81·7	80·1	79·9	79·8	79·4	77·6	75·3
27	74·5	77·4	79·8	82·4	85·1	81·9	80·1	80·1	79·1	80·1	77·6	74·1
28	75·0	77·0	80·1	82 7	85·0	82·1	79·5	79·6	79·7	79·1	77·8	74·3
29	74·0		79·8	82·3	85·4	82·6	80·0	79·3	79·6	79·6	77·0	75·1
30	73·5		79·8	82·1	85·4	82·4	79·8	78·8	79·4	79·5	77·4	74·6
31	72·9		79·6		85·3		80·1	78·8		79·9		73·7

The numbers enclosed within brackets, thus [ ], are interpolated from the means of the preceding and following days; they occur on days which have been regular holidays throughout the period.

TABLE 22.

SHOWING the NORMAL TEMPERATURE for each Day of the Typical Year derived from the Numbers in Table 21.

Date.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
1	74·0	73·3	76·3	79·9	83·1	85·1	81·9	79·9	79·6	79·8	79·7	77·9
2	73·8	73·3	76·4	80·0	83·2	85·0	81·9	79·8	79·6	79·9	79·6	77·8
3	73·7	73·4	76·5	80·1	83·2	85·0	81·9	79·7	79·6	80·0	79·6	77·8
4	73·7	73·3	76·5	80·2	83·4	84·9	81·9	79·7	79·6	80·0	79·5	77·7
5	73·6	73·3	76·6	80·3	83·5	84·9	81·8	79·7	79·6	80·1	79·4	77·7
6	73·6	73·3	76·6	80·4	83·6	84·8	81·6	79·6	79·7	80·2	79·3	77·6
7	73·6	73·3	76·6	80·5	83·7	84·8	81·3	79·6	79·7	80·3	79·2	77·5
8	73·6	73·4	76·7	80·6	83·7	84·6	81·1	79·6	79·8	80·3	79·2	77·4
9	73·5	73·6	76·8	80·8	83·8	84·4	80·9	79·6	79·9	80·4	79·1	77·4
10	73·5	73·7	76·9	80·9	83·8	84·2	80·7	79·6	79·9	80·5	79·1	77·2
11	73·4	73·8	77·0	81·0	83·8	84·0	80·5	79·6	79·9	80·6	79·0	77·1
12	73·4	73·9	77·1	81·1	83·9	83·8	80·4	79·5	79·9	80·6	78·9	77·0
13	73·4	74·0	77·3	81·2	83·9	83·5	80·2	79·5	79·9	80·7	78·8	76·8
14	73·5	74·2	77·5	81·3	83·9	83·3	80·1	79·5	79·9	80·8	78·7	76·6
15	73·6	74·4	77·7	81·4	83·9	83·1	79·9	79·4	79·9	80·9	78·6	76·5
16	73·6	74·5	77·9	81·6	84·0	82·9	79·8	79·5	79·8	80·9	78·5	76·3
17	73·7	74·7	78·1	81·7	84·0	82·7	79·6	79·5	79·8	80·9	78·4	76·2
18	73·7	74·9	78·2	81·8	84·1	82·5	79·5	79·6	79·7	80·9	78·3	76·0
19	73·7	75·1	78·4	81·9	84·2	82·4	79·4	79·6	79·7	80·8	78·2	75·9
20	73·7	75·3	78·6	82·0	84·2	82·2	79·4	79·6	79·7	80·7	78·2	75·8
21	73·7	75·5	78·7	82·1	84·3	82·1	79·5	79·7	79·6	80·7	78·1	75·7
22	73·7	75·7	78·8	82·1	84·4	82·0	79·5	79·6	79·6	80·6	78·1	75·5
23	73·7	75·8	79·0	82·2	84·4	82·0	79·6	79·6	79·6	80·5	78·0	75·4
24	73·6	75·8	79·1	82·3	84·5	82·0	79·6	79·6	79·6	80·4	78·0	75·3
25	73·6	75·9	79·2	82·4	84·6	82·0	79·7	79·5	79·6	80·3	77·9	75·1
26	73·6	75·8	79·3	82·5	84·7	82·0	79·7	79·5	79·6	80·2	77·9	75·0
27	73·6	76·1	79·4	82·6	84·8	81·9	79·7	79·5	79·6	80·1	77·9	74·9
28	73·6	76·2	79·5	82·8	84·9	81·9	79·8	79·5	79·7	80·0	77·9	74·7
29	73·5		79·6	82·9	85·0	81·8	79·8	79·5	79·7	79·9	77·9	74·5
30	73·4		79·7	83·0	85·0	81·8	79·9	79·5	79·8	79·8	77·9	74·3
31	73·4		79·8		85·1		79·9	79·6		79·7		74·2
Monthly means	73·6	74·5	77·9	81·5	84·1	83·3	80·3	79·6	79·7	80·4	78·6	76·3
Means. 1st fortnight*	73·6	73·6	76·8	80·7	83·6	84·4	81·1	79·6	79·8	80·3	79·2	77·3
Means. 2nd fortnight	73·6	75·4	79·0	82·3	84·5	82·1	79·7	79·6	79·7	80·4	78·1	75·3

*The division of the year into fortnights is invariably made according to the following rule:—The first 14 days of February and the first 15 of every other month make up the first fortnights of the several months, whilst the remaining days of each month are comprised in the second fortnight.

The mean temperature for the typical year is of necessity the same as the mean for the years 1866 to 1872, viz., 79°·2.

TABLE 23.

FIVE-DAY MEANS of TEMPERATURE of the AIR, derived from Observations taken in the Years 1866 to 1872.

Number of Five-day Period.	Corresponding Date.	Temperature.	Number of Five-day Period.	Corresponding Date.	Temperature.	Number of Five-day Period.	Corresponding Date.	Temperature.
1	January 1–5	74·0	25	May 1–5	83·6	50	September 3–7	79·8
2	6–10	72·8	26	6–10	83·8	51	8–12	80·0
3	11–15	74·2	27	11–15	83·9	52	13–17	80·0
4	16–20	73·4	28	16–20	83·9	53	18–22	79·6
5	21–25	73·5	29	21–25	84·5	54	23–27	79·4
6	26–30	74·1	30	26–30	85·1	55	28–32	79·7
7	31–35	73·3	31	31–35	85·6	56	October 3–7	80·1
8	February 5–9	72·5	32	June 5–9	84·9	57	8–12	80·6
9	10–14	74·0	33	10–14	84·1	58	13–17	80·7
10	15–19	75·2	34	15–19	82·4	59	18–22	81·3
11	20–24	75·1	35	20–24	81·6	60	23–27	80·2
12	25–29	77·0	36	25–29	82·0	61	28–32	79·4
13	March 2–6	76·0	37	30–34	82·2	62	November 2–6	79·9
14	7–11	76·6	38	July 5–9	81·7	63	7–11	79·3
15	12–16	77·7	39	10–14	80·1	64	12–16	78·2
16	17–21	78·4	40	15–19	79·3	65	17–21	78·5
17	22–26	79·2	41	20–24	79·4	66	22–26	77·9
18	27–31	79·8	42	25–29	80·0	67	27–31	77·5
19	April 1–5	79·8	43	30–34	79·8	68	December 2–6	78·3
20	6–10	80·8	44	August 4–8	80·0	69	7–11	77·4
21	11–15	81·3	45	9–13	79·3	70	12–16	76·5
22	16–20	81·8	46	14–18	79·6	71	17–21	76·1
23	21–25	82·4	47	19–23	79·4	72	22–26	75·3
24	26–30	82·3	48	24–28	80·0	73	27–31	74·3
			49	29–33	79·0			

The numbers in Tables 21 and 22 are curved in the usual manner in figure 2, the black ink curve referring to the simple means, and the red ink curve to the calculated daily normals.

62. On the latter curve we remark that between 15th July and 4th October the normal temperature never deviates more than 0°·3 from 79°·7; nor between 21st November and 5th December by more than 0°·2 from 77°·9; nor between 2nd January and 12th February by more than 0°·3 from 73°·6; nor between 6th and 20th May by more than 0°·3 from 83°·9; nor between 20th June and 5th July by more than 0°·2 from 82°·0; and these are the only periods of continued relative constancy of temperature which occur in the year. From 27th September till past the middle of October there is a gradual rise from 79°·6 to 80°·9, the influence of the monsoon rains, and cloudiness, which was predominant throughout the long preceding period of constancy, gradually giving place to that of a still favourable position of the sun; in October, however, this position is rapidly becoming less favourable, the sun's daily approach to the zenith of Bombay becoming less and less near, as the year advances, and after the 18th October less and less heat is daily received, and the temperature gradually sinks till the 12th January, when it has become 73°·4. The rate of fall during the parts of the last period which are mentioned above as of relative constancy is, of course,

extremely slow. The lowest temperature of the year (73°·3) appears on the 1st, 2nd, and 4th to 7th February, and between the 12th January and this time there has been a gradual slight rise of 0°·3, followed by a fall of 0°·4. From 7th February the temperature gradually rises to a maximum (of 85°·1) on 31st May and 1st June, after which there is a gradual descent till the end of June, when the monsoon influence has become again well established. From 7th to 20th June the fall is somewhat rapid, reaching 2°·6 in the 13 days, and there is a similar rapid fall of 2°·2 from 5th to 17th July. The range from the lowest to the highest normal daily temperature in the year is 11°·8. In individual years the range of temperature, from the greatest monthly mean to the least monthly mean, has its greatest value (12°·4) in 1872, and its least value (8°·8) in 1869.

63. *Diurnal variations.*—The algebraical excess of the mean temperature at a given hour in a given month—the mean referring to the years 1866 to 1872—above the mean temperature for all the 24 hours is taken as the diurnal inequality for the given hour; and similar excesses for all the hours represent the diurnal variation for that month. Such excesses for each month, for the winter and summer half years, and for the whole year, are exhibited in Table 24, and also by means of figures 39 to 53, with reference to the change from hour to hour in the several months, and by means of the curves of figure 193, with reference to the change from month to month at the several hours.

TABLE 24.

Hours of Civil Time.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	April to Sept.	Oct. to March.	Year.
0	−2°·8	−3°·0	−2°·6	−2°·5	−2°·5	−1°·4	−0°·9	−1°·0	−1°·5	−2°·4	−2°·9	−2°·7	−1°·6	−2°·7	−2°·2
1	−3·2	−3·4	−2·9	−2·8	−2·8	−1·6	−1·2	−1·2	−1·8	−2·7	−3·3	−3·1	−1·9	−3·1	−2·5
2	−3·7	−3·8	−3·2	−3·2	−3·1	−1·9	−1·2	−1·4	−1·9	−3·0	−3·7	−3·4	−2·1	−3·5	−2·8
3	−4·1	−4·4	−3·6	−3·6	−3·3	−2·0	−1·4	−1·6	−2·1	−3·2	−4·0	−3·8	−2·3	−3·9	−3·1
4	−4·5	−4·7	−4·1	−4·0	−3·6	−2·2	−1·5	−1·7	−2·3	−3·5	−4·3	−4·1	−2·5	−4·2	−3·4
5	−4·9	−5·1	−4·5	−4·4	−3·7	−2·4	−1·6	−1·8	−2·3	−3·8	−4·6	−4·4	−2·7	−4·6	−3·7
6	−5·2	−5·5	−5·0	−4·5	−3·6	−2·2	−1·6	−1·8	−2·4	−4·0	−4·9	−4·8	−2·6	−4·9	−3·8
7	−5·2	−5·3	−4·2	−2·7	−1·9	−1·5	−1·1	−1·4	−1·9	−3·0	−4·0	−4·5	−1·7	−4·4	−3·1
8	−3·2	−2·9	−1·7	−0·6	−0·3	−0·5	−0·4	−0·6	−0·9	−1·4	−2·1	−2·7	−0·5	−2·3	−1·5
9	−0·9	−0·7	+0·4	+1·1	+0·9	+0·5	+0·3	+0·2	+0·2	−0·1	−0·4	−0·9	+0·6	−0·4	0·0
10	+1·2	+1·5	+2·1	+2·2	+2·0	+1·5	+0·9	+1·0	+1·0	+1·2	+1·4	+0·8	+1·5	+1·4	+1·4
11	+3·1	+3·6	+3·4	+3·3	+3·1	+2·1	+1·5	+1·7	+2·0	+2·6	+3·2	+2·5	+2·3	+3·1	+2·6
12	+5·1	+5·2	+4·5	+4·4	+3·9	+2·7	+2·0	+2·2	+2·7	+4·1	+5·1	+4·5	+3·0	+4·8	+3·8
13	+6·4	+6·2	+5·3	+5·0	+4·6	+3·2	+2·4	+2·5	+3·3	+4·9	+6·4	+6·1	+3·5	+5·9	+4·7
14	+7·0	+6·7	+5·6	+5·3	+4·9	+3·3	+2·2	+2·6	+3·5	+5·4	+6·9	+6·8	+3·7	+6·4	+5·0
15	+7·0	+6·7	+5·5	+5·1	+4·7	+3·2	+2·0	+2·3	+3·4	+5·4	+6·6	+6·8	+3·5	+6·3	+4·9
16	+6·3	+6·2	+4·9	+4·4	+4·0	+2·7	+1·6	+1·8	+3·0	+4·7	+5·5	+5·9	+3·0	+5·6	+4·2
17	+3·8	+4·5	+3·7	+3·2	+2·8	+1·7	+0·7	+1·0	+1·8	+2·8	+2·8	+3·2	+1·9	+3·5	+2·6
18	+1·9	+1·8	+1·3	+0·9	+0·9	+0·5	0·0	+0·1	+0·4	+1·0	+1·3	+1·6	+0·5	+1·5	+0·9
19	+0·9	+0·6	+0·1	−0·3	−0·6	−0·3	−0·4	−0·4	−0·2	+0·1	+0·4	+0·8	−0·3	+0·5	0·0
20	+0·3	0·0	−0·4	−0·9	−1·2	−0·7	−0·6	−0·6	−0·5	−0·5	−0·3	+0·1	−0·7	−0·2	−0·5
21	−0·5	−0·7	−1·0	−1·4	−1·6	−1·0	−0·8	−0·7	−0·9	−1·1	−1·1	−0·7	−1·0	−0·9	−1·0
22	−1·4	−1·6	−1·5	−1·8	−1·9	−1·2	−0·9	−0·9	−1·1	−1·7	−2·2	−1·8	−1·3	−1·7	−1·5
23	−2·3	−2·3	−2·2	−2·1	−2·1	−1·3	−0·9	−1·0	−1·3	−2·2	−2·6	−2·4	−1·4	−2·3	−1·9

64. *Bessel's coefficients.*—Bessel's coefficients have been calculated for the diurnal variations of temperature, but for the period of five years only, from 1866 to 1870, and the following are the resulting expressions, θ in this case representing the hour, reckoned from six minutes after midnight, and converted into arc at the rate of 15° per hour:—

TABLE 25.

January	$\Delta T = 5{\cdot}42 \sin(\theta + 224^\circ\ 51') + 1{\cdot}77 \sin(2\theta + 49^\circ\ 7') + 0{\cdot}20 \sin(3\theta + 237^\circ\ 6') + 0{\cdot}40 \sin(4\theta + 249^\circ\ 16') + \&c.$
February	$\Delta T = 5{\cdot}54 \sin(\theta + 225\ 48) + 1{\cdot}71 \sin(2\theta + 53\ 20) + 0{\cdot}10 \sin(3\theta + 299\ 3) + 0{\cdot}40 \sin(4\theta + 221\ 59) + \&c.$
March	$\Delta T = 4{\cdot}62 \sin(\theta + 230\ 58) + 1{\cdot}45 \sin(2\theta + 62\ 54) + 0{\cdot}24 \sin(3\theta + 12\ 16) + 0{\cdot}41 \sin(4\theta + 244\ 3) + \&c.$
April	$\Delta T = 4{\cdot}42 \sin(\theta + 236\ 3) + 1{\cdot}22 \sin(2\theta + 65\ 45) + 0{\cdot}36 \sin(3\theta + 70\ 34) + 0{\cdot}34 \sin(4\theta + 256\ 22) + \&c.$
May	$\Delta T = 4{\cdot}07 \sin(\theta + 240\ 6) + 1{\cdot}03 \sin(2\theta + 58\ 56) + 0{\cdot}36 \sin(3\theta + 83\ 40) + 0{\cdot}24 \sin(4\theta + 257\ 44) + \&c.$
June	$\Delta T = 2{\cdot}59 \sin(\theta + 239\ 23) + 0{\cdot}81 \sin(2\theta + 55\ 32) + 0{\cdot}20 \sin(3\theta + 75\ 15) + 0{\cdot}15 \sin(4\theta + 250\ 21) + \&c.$
July	$\Delta T = 1{\cdot}66 \sin(\theta + 242\ 21) + 0{\cdot}64 \sin(2\theta + 65\ 2) + 0{\cdot}04 \sin(3\theta + 135\ 0) + 0{\cdot}08 \sin(4\theta + 284\ 2) + \&c.$
August	$\Delta T = 1{\cdot}90 \sin(\theta + 238\ 34) + 0{\cdot}73 \sin(2\theta + 60\ 39) + 0{\cdot}07 \sin(3\theta + 105\ 57) + 0{\cdot}10 \sin(4\theta + 258\ 41) + \&c.$
September	$\Delta T = 2{\cdot}71 \sin(\theta + 236\ 8) + 0{\cdot}89 \sin(2\theta + 54\ 10) + 0{\cdot}16 \sin(3\theta + 108\ 26) + 0{\cdot}19 \sin(4\theta + 231\ 20) + \&c.$
October	$\Delta T = 4{\cdot}13 \sin(\theta + 232\ 16) + 1{\cdot}30 \sin(2\theta + 47\ 49) + 0{\cdot}10 \sin(3\theta + 119\ 3) + 0{\cdot}25 \sin(4\theta + 265\ 26) + \&c.$
November	$\Delta T = 5{\cdot}20 \sin(\theta + 229\ 51) + 1{\cdot}68 \sin(2\theta + 50\ 33) + 0{\cdot}19 \sin(3\theta + 205\ 12) + 0{\cdot}36 \sin(4\theta + 281\ 19) + \&c.$
December	$\Delta T = 5{\cdot}17 \sin(\theta + 225\ 33) + 1{\cdot}71 \sin(2\theta + 42\ 38) + 0{\cdot}25 \sin(3\theta + 203\ 30) + 0{\cdot}37 \sin(4\theta + 273\ 6) + \&c.$
April to September	$\Delta T = 2{\cdot}89 \sin(\theta + 238\ 27) + 0{\cdot}89 \sin(2\theta + 60\ 15) + 0{\cdot}19 \sin(3\theta + 83\ 59) + 0{\cdot}18 \sin(4\theta + 253\ 37) + \&c.$
October to March	$\Delta T = 5{\cdot}01 \sin(\theta + 228\ 0) + 1{\cdot}60 \sin(2\theta + 50\ 50) + 0{\cdot}07 \sin(3\theta + 225\ 0) + 0{\cdot}34 \sin(4\theta + 254\ 45) + \&c.$
Year	$\Delta T = 3{\cdot}93 \sin(\theta + 231\ 49) + 1{\cdot}23 \sin(2\theta + 54\ 15) + 0{\cdot}07 \sin(3\theta + 98\ 8) + 0{\cdot}26 \sin(4\theta + 254\ 21) + \&c.$

65. And from the expressions in the last three lines have been calculated the times of occurrence of the maximum and minimum temperatures in the variations for the year, and for the two half years, and the corresponding inequalities; also the times of most rapid rise and fall of temperature, and the rates of increase and decrease. These are as follows:—

TABLE 26.

	Maximum.		Minimum.		Most rapid Rise.		Most rapid Fall.	
	Inequality.	Time of Occurrence.	Inequality.	Time of Occurrence.	Rate per Hour.	Time of Occurrence.	Rate per Hour.	Time of Occurrence.
		h. m.		h. m.		h. m.		h. m.
April to September	+ 6°·6	14 21	− 4°·9	5 1	+ 1°·2	8 16	− 1°·2	17 16
October to March	+ 3·7	14 26	− 2·7	5 44	+ 2·1	8 57	− 1·8	17 5
Year	+ 5·1	14 23	− 3·8	5 28	+ 1·6	8 41	− 1·5	17 10

66. There is a relatively sudden change of movement of the thermometer about the times of sunrise, which, unless the observations were taken much oftener than once an hour, and Bessel's formula developed to a great number of terms, this method is incapable of exhibiting; the essential property of the method is to find a smooth-flowing variation which shall nearly represent the actual variation, whilst toning down, as it were, any suddenness or irregularity in the latter. Consequently the sharp feature which occurs in the temperature

variation near sunrise is rounded off so as to throw the minimum of temperature to that side of the actual minimum in which the rate of change of temperature is least, that is, towards the night hours. The fact of the relative suddenness of change of movement of the thermometer near sunrise, which could only be surmised from the consideration of hourly observations, is confirmed by an inspection of the continuous photographic registrations of temperature of the years 1873 and 1874. For the reason just stated, the times of minimum temperature given in Table 26 are of little value, whilst those of maximum temperature, about which no sudden movements occur, are doubtless very exact.

67. *Time of occurrence of minimum.*—We observe in figures 39 to 53 that for many hours before and after sunrise the curves approximate in form very closely to straight lines, implying that during these hours, but with the exception of a short time about sunrise, the rate of change of temperature is nearly uniform. The hour in which the change takes place, from the uniform fall of temperature of the night, to the nearly uniform rise of the day, is distinctly marked in every month's curve, except that of August, in which the change is divided between two hours. We may obtain a nearer approximation to the time of minimum temperature than is given by Bessel's formula, by continuing onward the uniform night fall of temperature, and backward the uniform day rise, until they give the same temperature. We choose, as least open to objection, for the rate of fall at night, the rate of the last hour which decidedly precedes the change; and for the rate of rise in the day, the rate of the first hour after which the change has decidedly passed: thus, in the mean diurnal variation for the month of January we take $-0°{\cdot}3$, the diminution of temperature from 5 to 6 hours,* as the night-rate, and $+2°{\cdot}0$, the increase of temperature from 7 to 8 hours, as the day rate; these with the inequalities $-5°{\cdot}2$ and $-5°{\cdot}2$ at 6 and 7 hours respectively give the time of minimum as $6^h\ 58^m$. Similarly the times for the other months are as follows:—February, $6^h\ 53^m$; March, $6^h\ 40^m$; April, $5^h\ 58^m$; May, $5^h\ 59^m$; June, $5^h\ 39^m$; July, $5^h\ 56^m$; August, $6^h\ 26^m$; September, $6^h\ 33^m$; October $6^h\ 26^m$; November, $6^h\ 33^m$; December, $6^h\ 47^m$; and the mean times for the half years, April to September and October to March, are $6^h\ 5^m$ and $6^h\ 43^m$ respectively, the first being about 29 minutes, and the last about 25 minutes, after the average time of sunrise for the half year.

A somewhat abrupt movement, similar to the one already noticed as occurring about sunrise, is distinctly, though less strongly, marked, near the time of sunset, and it is like sunset, clearly later in occurrence in the summer than in the winter months.

68. An inspection of figures 39 to 53 shows at once that the law of the diurnal variation, but not the amplitude of the variation, is of nearly the same character throughout the year: the diurnal range, whilst only $5°{\cdot}1$ on the average for the monsoon months, June to September, is as much as $12°{\cdot}0$ during the months November to February, and has intermediate values in the other months.

In the mean diurnal variation for the year the minimum occurs at $6^h\ 24^m$, and the maximum at $14^h\ 23^m$, the respective inequalities being $-3°{\cdot}8$ and $+5°{\cdot}1$. From soon after sunrise to sunset the curve approximates in form to a curve of sines, and from sunset

* Although for shortness we speak of the observations as of 5 hours and 6 hours, it is always to be understood that they really refer to the times $5^h\ 6^m$ and $6^h\ 6^m$, and due account is taken of the six minutes in recording the times of maximum, minimum, &c.

till near sunrise the fall of temperature is continuous, and, except at the earlier hours, when the fall is somewhat more rapid, almost uniform.

In figure 193 we notice a rough approximation to the symmetry of arrangement of successive hour lines, which is indicative of a similar law of diurnal variation in the different seasons. The most marked departures from this symmetry occur at 9 and 10 hours in the months March, April, and May, at which hours the rising movement of the thermometer is in advance of the corresponding movement in the rest of the year, and at 19, 20, and 21 hours, when the falling movement is similarly in advance, in the month of May. In the months November, December, January, and February, when the range of the diurnal variation is greatest, both the character and range of the variation remain remarkably constant, although there is a slight but clearly marked diminution of range in December.

69. The range of the mean diurnal variation of temperature in different years varies between 9°·1 in 1866, and 8°·4 in 1869, showing a difference of one thirteenth of the sun's average daily heating effect. The ranges for the years 1866 to 1872 in order are 9°·1, 8°·8, 9°·0, 8°·4, 8°·5, 8°·8, and 8°·9. The suggestion of a periodicity carried by these numbers, neglecting the one for 1868,—in that starting with a maximum they decrease gradually to a minimum, and then increase again to a maximum,—is marred by the occurrence of the irregular value excepted; but, as showing small values near the times when the sun-spot period is at a maximum, and as being in agreement in this respect with the ranges of the next preceding sun-spot period, the apparently systematic progression is worthy of mention. For the years 1853 to 1865 the mean diurnal ranges in order are 10°·8, 10°·0, 10°·2, 10°·1, 9°·9, 10°·0, 9°·8, 9°·7, 9°·9, 10°·1, 10°·0, 10°·1, and 9·9, giving a mean range of 9°·9 for the five middle years 1857 to 1861, which are near the maximum of sun-spots, and 10°·2; for the mean of the eight extreme years. It will be seen later (paragraph 76) that the mean vapour pressure about the years when the aggregate area of sun-spots is in excess of the average is greater than about the years when that aggregate is in defect. The absorbing power of the atmosphere being thus in excess in the former years, less of the sun's heat will penetrate to the ground surface, and the daily rise of temperature of the air will, as compared with years of deficient sun-spots, be contracted: so we find it to be.

70. *Variability.*—This we propose to exhibit in the same form that we have adopted for showing the variability of barometric pressure; first, by means of the extreme temperatures observed in each year and month; secondly, by the relative frequency of observations in each degree of the thermometer scale, and in each fortnight of the year; and, thirdly, by means of probable errors of the normal temperature of each fortnight, calculated from the daily abnormals of temperature of the three years 1868 to 1870.

TABLE 27.

SHOWING the GREATEST and LEAST TEMPERATURES observed in each of the Years 1847 to 1872.

YEAR.	INDIVIDUAL HOURS.									DAILY MEANS.						MONTHLY MEANS.				
	Maximum.				Minimum.				Extreme Range in Year.	Maximum.		Minimum.		Range in Year.		Maximum.		Minimum.		Range in Year.
	Temperature.	Time of Occurrence.			Temperature.	Time of Occurrence.				Temperature.	Date of Occurrence.	Temperature.	Date of Occurrence.			Temperature.	Month.	Temperature.	Month.	
		hr.	day.	mth.		hr.	day.	mth.			day.	mth.	day.	mth.						
1847	94°2	10	17	4	53°3	6	3	2	40°9	86°5	24	5	62°2	2	2	24°3	83°9	5	73°7	2	10°2
1848	98·0	12	20	3	57·0	6	7	2	41·0	86·7	23	5	67·1	6	2	19·6	84·6	5	75·1	2	9·5
1849	96·5	12	3	11	58·5	6	18	1	38·0	86·6	31	5	65·9	17	1	20·7	85·2	5	73·3	1	11·9
1850	97·0	10	25	4	60·0	6	2	2	37·0	87·8	6	6	68·1	1	2	19·7	84·4	5	72·4	1	12·0
1851	93·3	12	22	2	57·3	7	21	1	36·0	86·7	27	5	65·6	20	1	21·1	84·6	5	72·2	1	12·4
1852	95·4	15	5	6	57·4	6	23	1	38·0	88·3	10	6	66·7	22	1	21·6	86·3	5	71·9	1	14·4
1853	96·4	13	7	6	58·6	7	22	1	37·8	89·4	7	6	67·0	24	1	22·4	86·9	5	71·6	1	15·3
1854	98·4	14	10	3	63·0	6	3	2	35·4	89·4	3	6	71·3	2	2	18·1	86·9	5	75·0	2	11·9
1855	95·3	13	2	6	60·0	7	18	1	35·3	88·5	2	6	69·2	18	1	19·3	86·0	5	74·7	1	11·3
1856	94·6	14	26	5	63·0	6	9	12	31·6	88·1	26	5	72·6	9	12	15·5	86·1	5	75·4	12	10·7
1857	100·2	13	18	3	63·0	7	28	1	37·2	87·6	29	5	70·9	28	1	16·7	86·1	5	73·9	12	12·2
1858	94·9	13	1	5	60·8	6	27	1	34·1	88·0	1	5	69·0	27	1	19·0	86·2	5	73·3	1	12·9
1859	98·4	12	21	3	62·0	6	3	12	36·4	88·0	1	6	69·7	5	1	18·3	85·2	5	74·2	12	11·0
1860	93·7	14	31	5	59·6	7	24	1	34·1	88·1	2	6	68·3	24	1	19·8	85·0	5	72·3	1	12·7
1861	97·0	13	12	3	62·5	6	23	1	34·5	87·6	30	5	70·6	23	1	17·0	85·2	5	74·4	12	10·8
1862	94·0	14	6	2	61·4	6	17	1	32·6	87·8	6	6	69·6	17	1	18·2	85·8	5	72·9	1	12·9
1863	95·0	15	21	2	60·2	7	23	1	34·8	87·9	4	6	67·3	23	1	20·6	86·0	5	74·3	1	11·7
1864	94·0	14	2	6	60·7	6	25	1	33·3	87·6	31	5	68·9	16	1	18·7	84·4	6	71·3	1	13·1
1865	96·0	14	30	5	66·1	6	28	12	29·9	89·5	30	5	73·2	28	12	16·3	87·6	5	77·0	2	10·6
1866	91·8	15	29	10	56·6	6	6	1	35·2	86·3	9	6	65·3	9	2	21·0	82·7	5	71·8	2	10·9
1867	92·6	14	5	6	61·8	7	27	12	30·8	87·4	4	6	70·0	20	2	17·4	84·7	5	73·1	2	11·6
1868	92·5	14	6	6	62·2	7	31	1	30·3	85·9	30	5	69·4	7	1	16·5	84·5	5	72·9	1	11·6
1869	92·4	14	2	6	63·3	6	10	2	29·1	86·4	29	5	72·2	6	2	14·2	84·1	5	75·3	1	8·8
1870	92·7	13	21	2	62·9	7	22	1	29·8	86·3	6	6	68·9	17	1	17·4	83·7	5	73·6	1	10·1
1871	93·3	14	10	4	66·1	7	24	1	27·2	86·7	1	5	70·6	16	1	16·1	85·6	5	74·9	1	10·7
1872	93·3	14	11	6	60·4	7	25	1	32·9	86·7	10	6	68·1	25	1	18·6	84·1	5	71·7	1	12·4

The greatest temperature observed at any hour in the period of 26 years was 100°·2 at 1 p.m. of the 18th March 1857; and the least was 53°·3 at 6 a.m. of the 3rd February 1847. The greatest mean daily temperature was 89°·5 on the 30th May 1865, and the least 62°·2 on the 2nd February 1847; and the greatest monthly mean temperature was 87°·6 for May 1865, and the least 71·3 for January 1864.

TABLE 28.

SHOWING the GREATEST and LEAST TEMPERATURES observed in each Month of the same name in any of the Years 1847 to 1872, for every Month of the Year.

Month.	Individual Hours.					Daily Means.				
	Maximum.		Minimum.		Extreme Range in Month.	Maximum.		Minimum.		Range in Month.
	Temperature.	Time of Occurrence.	Temperature.	Time of Occurrence.		Temperature.	Date of Occurrence.	Temperature.	Date of Occurrence.	
	°	hr. day. yr.	°	hr. day. yr.	°	°	date. year.	°	date. year.	°
January	91·0	15 21 1859	56·6	6 6 1866	34·4	79·7	21 1857	65·4	6 1866	14·3
February	96·2	13 19 1861	53·3	6 3 1847	42·9	82·1	7 1869	62·2	2 1847	19·9
March	100·2	13 18 1857	64·7	7 6 1868	35·5	85·2	18 1857	72·1	6 1868	13·1
April	97·4	12 28 1859	69·3	22 6 1848	28·1	87·6	28 1859	75·9	3 1866	11·7
May	96·2	14 28 1854	75·7	6 5 1847	20·5	89·5	30 1865	81·6	1 1868	7·9
June	96·4	13 7 1853	72·5	8 30 1847	23·9	89·4	7 1853	75·6	29 1847	13·8
July	92·4	15 7 1859	71·9	10 16 1868	20·5	86·3	7 1859	75·5	21 1866	10·8
August	89·6	14 1 1865	73·0	14 18 1848	16·6	84·3	1 1865	75·8	31 1853	8·5
September	94·0	17 29 1864	70·5	10 9 1847	23·5	84·8	29 1864	73·4	8 1847	11·4
October	95·7	13 19 1850	71·0	5 27 1851	24·7	86·5	13 1850	76·6	26 1872	9·9
November	96·5	12 3 1849	62·7	6 30 1847	33·8	84·5	3 1850	71·4	28 1847	13·1
December	94·0	13 27 1849	61·7	6 22 1848	32·3	82·0	4 1862	70·0	27 1867	12·0

The vertical lines of figures 196 and 197 have been drawn to represent the extreme temperatures and the range of temperature in each year and in each month that are shown in Tables 27 and 28 respectively, the red lines referring to observations at individual hours, the black lines to daily means, and the violet lines to monthly means.

71. The principal point that we notice in figure 196 is that, dividing the 26 years into (say) three periods of eight, nine, and nine years, the average lengths of the lines gradually diminish, and this is shown in the extreme ranges, hourly, daily, and monthly. The corresponding mean numbers are as follows :—

TABLE 29.

MEAN MAXIMUM and MEAN MINIMUM TEMPERATURES of the periods 1847 to 1854, 1855 to 1863, and 1864 to 1872, in Hours, Days, and Months.

Periods.	At Individual Hours.			Daily Means.			Monthly Means.		
	Mean Maximum.	Mean Minimum.	Range.	Mean Maximum.	Mean Minimum.	Range.	Mean Maximum.	Mean Minimum.	Range.
	°	°	°	°	°	°	°	°	°
1847 to 1854	96·1	58·1	38·0	87·7	66·7	21·0	85·3	73·1	12·2
1855 to 1863	95·9	61·4	34·5	88·0	69·7	18·3	85·7	73·9	11·8
1864 to 1872	93·2	62·2	31·0	87·0	69·6	17·4	84·6	73·5	11·1

Almost exactly equal differences are shown in the extreme ranges, hourly and daily, when the periods taken are 1847 to 1850, 1851 to 1865, and 1866 to 1872, which are the

periods of exposure of the thermometers in the small shed, in the large shed, and in the thermometer cage respectively; but we are indisposed to regard them as simply due to difference of exposure, because the rise of the mean minimum temperature is as noticeable as the fall of the mean maximum temperature.

In figure 197 we note the relatively small length of the red lines for May to October, showing that the absolute range of the thermometer is in those months much smaller than in the months November to April; whilst of the black lines those of May and August are notably shorter than any others, implying that in those months the mean daily temperature is more nearly constant than in any other.

TABLE 30.

72. SHOWING the NUMBER of OCCURRENCES of MEAN DAILY TEMPERATURES, in each degree of the THERMOMETER SCALE, during the same Fortnight in all the Years 1847 to 1872,* and for each Fortnight in the Year.

Mean Daily Temperature lying between	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		Dec.	
	FORTNIGHT.																							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
62·1 and 63·0			1																					
63·1 and 64·0																								
64·1 and 65·0																								
65·1 and 66·0	2	2	1																					
66·1 and 67·0		3	1																					
67·1 and 68·0		5	2																					
68·1 and 69·0	3	13	3																					
69·1 and 70·0	7	22	4	1																				1
70·1 and 71·0	17	22	11	3																			1	2
71·1 and 72·0	20	27	19	4																		3	3	6
72·1 and 73·0	42	41	28	11	1																1		5	16
73·1 and 74·0	55	45	45	16	7												1				2	3	16	46
74·1 and 75·0	38	38	47	35	20	1															2	8	23	59
75·1 and 76·0	53	50	46	50	35	1	1					1		2		1	4	2			7	24	56	77
76·1 and 77·0	40	33	45	70	52	15	2						1	6	4	10	5	3	3	1	5	52	60	53
77·1 and 78·0	23	24	27	47	61	21	1				2	6	11	28	17	23	24	11	5	14	39	47	46	36
78·1 and 79·0	6	11	15	33	52	55	9				8	15	33	40	32	52	36	33	12	23	59	43	59	16
79·1 and 80·0		6	1	14	34	56	42	10			17	34	29	69	71	85	77	77	40	50	56	57	29	5
80·1 and 81·0				12	19	56	51	18			20	34	42	60	91	71	81	108	80	57	58	53	15	1
81·1 and 82·0			1	1	17	62	57	46	7	3	31	46	48	84	60	67	66	59	65	80	50	23	5	
82·1 and 83·0			1		6	32	59	75	39	10	26	65	66	28	30	26	22	22	68	64	14	11		
83·1 and 84·0					3	21	54	57	68	26	37	51	49	14	5	1	3	5	44	36	14			
84·1 and 85·0						8	24	59	81	75	34	36	32	10	1			2	11	7	3			
85·1 and 86·0						1	10	27	62	86	66	24	9											
86·1 and 87·0							1	22	46	90	32	5	1						1					
87·1 and 88·0								3	14	22	30	4												
88·1 and 89·0									4	17	11													
89·1 and 90·0										2	3													
Totals	303	342	298	297	307	329	311	317	321	331	317	321	321	341	311	336	319	322	324	332	310	324	318	318

* Excepting the year 1852, during which the air thermometer was changed.

TABLE 31.

PROBABILITIES of OCCURRENCE of MEAN DAILY TEMPERATURES within each degree of the THERMOMETER SCALE.

Mean Daily Temperature lying between	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		Dec.	
	FORTNIGHT.																							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
62·1 and 63·0			·003																					
63·1 and 64·0																								
64·1 and 65·0																								
65·1 and 66·0	·007	·006	·003																					
66·1 and 67·0		·009	·003																					
67·1 and 68·0		·015	·007																					
68·1 and 69·0	·010	·038	·010																					
69·1 and 70·0	·023	·064	·013	·003																				·003
70·1 and 71·0	·056	·064	·036	·010																			·003	·006
71·1 and 72·0	·065	·079	·063	·013																		·009	·009	·019
72·1 and 73·0	·137	·120	·094	·037	·003																·003		·016	·050
73·1 and 74·0	·180	·131	·151	·054	·023												·003				·006	·009	·050	·145
74·1 and 75·0	·124	·111	·157	·118	·065	·003															·006	·025	·072	·186
75·1 and 76·0	·173	·146	·155	·169	·114	·003	·003					·003		·006		·003	·012	·006			·022	·075	·176	·242
76·1 and 77·0	·131	·097	·151	·236	·169	·045	·006						·003	·018	·012	·030	·015	·009	·009	·003	·016	·160	·189	·167
77·1 and 78·0	·075	·070	·091	·158	·199	·063	·003				·006	·018	·034	·082	·054	·069	·075	·034	·015	·042	·126	·145	·145	·113
78·1 and 79·0	·020	·033	·050	·111	·169	·167	·029				·025	·047	·103	·117	·103	·155	·113	·103	·037	·069	·191	·133	·186	·050
79·1 and 80·0		·018	·003	·047	·110	·170	·135	·032			·053	·106	·091	·202	·229	·253	·242	·239	·123	·150	·181	·176	·091	·016
80·1 and 81·0				·040	·062	·170	·164	·057			·063	·106	·131	·176	·292	·211	·254	·335	·247	·171	·187	·164	·047	·003
81·1 and 82·0			·003	·003	·055	·188	·184	·145	·022	·009	·098	·144	·150	·246	·193	·199	·207	·183	·201	·240	·162	·071	·016	
82·1 and 83·0			·003		·020	·098	·190	·236	·121	·030	·082	·203	·206	·082	·097	·078	·069	·068	·194	·192	·044	·034		
83·1 and 84·0					·010	·063	·174	·180	·212	·078	·117	·159	·152	·041	·016	·003	·009	·015	·136	·108	·044			
84·1 and 85·0						·024	·077	·186	·252	·227	·108	·113	·100	·029	·003			·006	·034	·021	·009			
85·1 and 86·0						·003	·032	·085	·194	·260	·209	·075	·028											
86·1 and 87·0							·003	·070	·143	·272	·101	·015	·003						·003					
87·1 and 88·0								·009	·044	·066	·095	·012												
88·1 and 89·0									·012	·051	·035													
89·1 and 90·0										·006	·009													
Fortnightly means	74·1	73·7	74·6	76·5	77·8	80·3	81·9	83·3	84·7	85·6	84·2	82·4	81·7	80·4	80·3	80·1	80·0	80·1	81·5	81·1	79·7	78·5	77·0	75·4

The probabilities of this table are exhibited graphically by means of the double stepped pyramids of figure 208.

73. In some fortnights we notice a decided predominance of temperatures not far removed from the normal temperature, as in the second half of February and last half of December, whilst in others there is a range of several degrees about the normal, in any part of which it is equally probable that a single day's mean temperature will lie, as between 72° and 77° in January, between 73° and 77° in the first fortnight of February, between 78° and 82° in the second fortnight of March, and in the first fortnight of November, between 76° and 81° in the second fortnight of November, and between 75° and 79° in the first fortnight of December. In May, August, and September the pyramids are, relatively to the rest, broad and short; implying that, on the whole, the amplitude of

variation of the mean daily temperature is in those months less than in other parts of the year. This character of the months of May and August we could discern less certainly from the lines of figure 197, the extremities of which represent single observations only, but by considering the whole body of observations we now learn that it distinguishes September also.

For numerical measures of the variability of temperature we must resort, however, to the method of probable errors.

TABLE 32.

74. PROBABLE ERRORS of MEAN DAILY TEMPERATURE in each FORTNIGHT of the YEAR, or the PROBABLE DIFFERENCES between the observed MEAN TEMPERATURE of a SINGLE DAY and the NORMAL TEMPERATURE, derived from the DAILY ABNORMALS of the three Years 1868 to 1870.

Month	January.		February.		March.		April.		May.		June.	
Fortnight	1	2	1	2	1	2	1	2	1	2	1	2
$\Sigma(a^2)$	127·82	201·28	77·07	190·31	124·05	59·84	69·29	45·84	18·05	15·13	80·22	124·73
$n-1$	35	39	34	33	36	39	36	38	37	36	38	38
Probable error (r)	1·29	1·53	1·02	1·62	1·25	0·84	0·94	0·74	0·47	0·44	0·98	1·22

TABLE 32—*continued.*

Month	July.		August.		September.		October.		November.		December.	
Fortnight	1	2	1	2	1	2	1	2	1	2	1	2
$\Sigma(a^2)$	206·31	79·22	54·65	84·55	39·42	44·31	60·31	73·85	96·32	77·95	100·38	66·00
$n-1$	38	40	35	39	38	38	38	37	36	38	38	39
Probable error (r)	1·57	0·95	0·84	0·99	0·69	0·73	0·85	0·95	1·11	0·96	1·10	0·88

The meaning of the first number in the last line is, that in the first fortnight of January more than half the mean daily temperatures lie within $\pm$ 1°·29 of the normal means of the respective days, and similarly for the rest. The probable error for the year is $\pm$ 1°·03, or it is more likely that the actual mean temperature of any day in the year, taken haphazard, will be within than without the temperature limits of 1°·03 above, and 1°·03 below the normal temperature of the day.

Combining together successive fortnights of nearly equal probable errors we obtain—

From 1st January to 15th March	— probable error	= 1°·34
From 16th March to 30th April	— ,,	= 0·84
From 1st May to 31st May	— ,,	= 0·45
From 1st June to 15th July	— ,,	= 1·26
From 16th July to 31st August	— ,,	= 0·93
From 1st September to 15th October	— ,,	= 0·76
From 16th October to 31st December	— ,,	= 1·00

Here we see that in respect of temperature the most disturbed parts of the year are from 1st January to 15th March, and from 1st June to 15th July; the least disturbed is May, in

which month the probability is that the mean of one set of 24 hourly observations will be within half a degree of the normal temperature of the day; and there is a secondary minimum of disturbance from 1st September to 15th October. These probable errors are derived from only three years' abnormals, whilst the probabilities of Table 31 are derived from 25 years' observations; but even here, August and September, with exception of the second half of August, are as before, months of comparative steadiness of the air thermometer.

75. *Pressure of vapour.*—The pressure of vapour has been calculated by different approximations to Apjohn's formula in different periods; the exact formula is—

$$f'' = f' - \cdot 001147\ (t - t') \times \frac{p - f'}{30}$$

in which t and t' denote the temperatures of the dry bulb and wet bulb thermometers respectively; f'' and f' represent respectively the elastic force of aqueous vapour at the temperature of the dew-point and at temperature t', and p is the pressure of the barometer.

The formulæ used are—

$$\text{From 1847 to 1861, } f'' = f' - \cdot 00114\ (t - t').$$

$$\text{From 1862 to 1865, } f'' = f' - \cdot 001147\ (t - t') \times \frac{29 \cdot 8 - f'}{30}$$

29·8 being very nearly the mean barometric pressure for the year at Bombay; and from 1866 to 1872 the calculation was made by means of tables which give values that always agree within ·001 inch, with the results of direct applications of the exact expression.

The following table—constructed by the formula of Biot, which was devised to accord with the values found experimentally by Dalton—gives, for different temperatures, the values of the maximum elastic force of aqueous vapour that were used until the end of the year 1865.

TABLE 33.

Temperature, Fahr.	Elastic Force of Vapour.	Temperature, Fahr.	Elastic Force of Vapour.	Temperature, Fahr.	Elastic Force of Vapour.	Temperature, Fahr.	Elastic Force of Vapour.	Temperature, Fahr.	Elastic Force of Vapour.
°	inch.	°	inch.	°	inch.	°	inch.	°	inch.
40	·264	50	·373	60	·523	70	·726	80	1·001
41	·273	51	·386	61	·541	71	·750	81	1·033
42	·283	52	·400	62	·559	72	·775	82	1·066
43	·293	53	·414	63	·578	73	·801	83	1·100
44	·304	54	·428	64	·597	74	·827	84	1·135
45	·315	55	·442	65	·617	75	·854	85	1·171
46	·326	56	·457	66	·638	76	·882	86	1·208
47	·337	57	·473	67	·659	77	·911	87	1·246
48	·349	58	·489	68	·681	78	·940	88	1·286
49	·361	59	·506	69	·703	79	·970	89	1·326

From the beginning of 1866 to the present time Regnault's later determinations of the maximum pressure of vapour at different temperatures were adopted instead of Biot's. These are shown in Table 34.

TABLE 34.

Temperature.	Tension of Vapour.	Temperature.	Tension of Vapour.	Temperature.	Tension of Vapour.	Temperature.	Tension of Vapour.	Temperature.	Tension of Vapour.
°		°		°		°		°	
35	·204	48	·335	61	·537	74	·839	87	1·282
36	·212	49	·348	62	·556	75	·868	88	1·324
37	·220	50	·361	63	·576	76	·897	89	1·366
38	·229	51	·374	64	·596	77	·927	90	1·410
39	·238	52	·388	65	·617	78	·958	91	1·455
40	·248	53	·403	66	·639	79	·990	92	1·501
41	·257	54	·418	67	·662	80	1·023	93	1·548
42	·267	55	·433	68	·685	81	1·057	94	1·597
43	·278	56	·449	69	·709	82	1·092	95	1·647
44	·288	57	·466	70	·733	83	1·128	96	1·698
45	·299	58	·482	71	·758	84	1·165	97	1·751
46	·311	59	·500	72	·784	85	1·203	98	1·805
47	·323	60	·518	73	·811	86	1·242		

For the same reason that was given in treating the observations of temperature of the air, viz., that the exposure of the thermometers was unlike in different periods, and because no corrections were applied for errors of graduation of the thermometers before 1866, the examination of periodical variations of vapour pressure will be confined to the observations of 1866 to 1872.

TABLE 35.

MONTHLY and ANNUAL MEANS of PRESSURE of VAPOUR, expressed in Inches of Mercury, for the Years 1847 to 1872.

YEAR.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	YEAR.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
1847	·633	·606	·758	·832	·898	·934	·907	·890	·851	·890	·693	·646	·795
1848	·643	·629	·727	·860	·888	·918	·909	·873	·866	·909	·733	·676	·803
1849	·588	·661	·727	·804	·861	·969	·916	·892	·872	·858	·805	·601	·796
1850	·566	·596	·723	·783	·887	·942	·935	·892	·858	·889	·694	·648	·784
1851	·555	·639	·741	·839	·858	·929	·918	·890	·828	·861	·731	·590	·782
1852	·508	·637	·707	·800	·844	·920	·906	·873	·877	·858	·676	·627	·769
1853	·511	·617	·712	·818	·894	·934	·897	·854	·855	·776	·709	·598	·765
1854	·595	·557	·716	·840	·907	·946	·924	·895	·899	·846	·732	·688	·795
1855	·596	·664	·717	·793	·935	·947	·919	·863	·875	·869	·714	·634	·794
1856	·642	·625	·787	·849	·900	·933	·917	·873	·841	·842	·707	·634	·796
1857	·628	·674	·793	·822	·933	·910	·920	·894	·862	·827	·675	·566	·792
1858	·625	·650	·769	·875	·968	·923	·947	·911	·880	·858	·707	·669	·815
1859	·652	·693	·732	·852	·890	·956	·957	·890	·888	·853	·742	·608	·809
1860	·562	·654	·737	·834	·887	·956	·948	·893	·893	·922	·650	·668	·800
1861	·565	·612	·696	·822	·890	·921	·910	·883	·850	·839	·673	·598	·772
1862	·553	·619	·653	·785	·851	·922	·934	·906	·915	·868	·747	·582	·778
1863	·597	·577	·698	·836	·855	·902	·879	·863	·835	·818	·671	·583	·759
1864	·484	·561	·651	·768	·825	·900	·900	·871	·870	·805	·705	·632	·748
1865	·625	·607	·693	·883	·906	·930	·917	·901	·841	·833	·677	·651	·789
1866	·586	·545	·707	·768	·848	·932	·909	·895	·861	·854	·648	·596	·762
1867	·598	·560	·722	·819	·912	·947	·909	·903	·873	·860	·657	·647	·784
1868	·583	·663	·674	·814	·905	·953	·902	·879	·868	·868	·688	·622	·785
1869	·629	·608	·691	·832	·875	·930	·919	·908	·887	·815	·664	·689	·787
1870	·566	·613	·698	·797	·837	·915	·895	·861	·856	·859	·755	·613	·772
1871	·632	·641	·720	·856	·900	·915	·890	·860	·863	·873	·786	·666	·800
1872	·515	·535	·737	·789	·839	·925	·901	·866	·878	·797	·645	·671	·758
Means for 26 Years	·586	·617	·719	·822	·884	·931	·915	·884	·867	·852	·703	·631	·784

76. *Five-year means.*—The mean values of the pressure of vapour for the five-year periods of the Vienna Congress are, 1851 to 1855, ·781 inch; 1856 to 1860, ·802 inch; 1861 to 1865, ·769 inch; and 1866 to 1870, ·778 inch. The mean pressure of vapour for the seven years 1866 to 1872 is ·778 inch. The yearly means of vapour pressure may, like

those of barometric pressure, be divided into groups which show a variation having a decennial period; in this case, however, an excess of vapour pressure occurs at the phase of the sun-spot period corresponding to an excess of spot-area, and a defect of vapour pressure during groups of years intervening between successive groups of excess vapour pressure. Thus, for 1847 to 1849 the mean vapour pressure is ·798 inch; for 1850 to 1853, ·775; for 1854 to 1860, ·800; for 1861 to 1866, ·768; and for 1867 to 1871 it is ·786 inch,—mean numbers which it will be noticed are alternately relatively large and small.

77. *Annual variation.*—Normal values of the pressure of vapour have been calculated for each day in the year, by the same method that has been described as having been applied to barometric pressure and temperature of the air, viz., by taking fifteen day means, after performing six smoothing operations. The results are shown in Table 37, and the simple means for each day in Table 36.

TABLE 36.

SHOWING the MEAN PRESSURE of VAPOUR of each Day of the Year, derived from the Observations of the Years 1866 to 1872.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	November.	December.
1	[·618]	·567	·634	·751	·867	·927	·916	·897	·876	·883	·742	·691
2	·642	·575	·646	·737	·876	·933	·919	·890	·868	·891	·743	·731
3	·646	·602	·610	·770	·868	·923	·913	·890	·874	·898	·754	·706
4	·594	·555	·623	·772	·898	·926	·910	·895	·873	·872	·781	·689
5	·531	·541	·675	·790	·891	·931	·904	·894	·860	·870	·708	·659
6	·519	·523	·624	·767	·892	·946	·903	·906	·863	·896	·683	·674
7	·572	·549	·684	·778	·866	·921	·908	·897	·861	·878	·696	·652
8	·561	·546	·677	·790	·866	·933	·905	·888	·851	·887	·705	·641
9	·607	·578	·682	·804	·849	·957	·917	·892	·852	·893	·685	·611
10	·610	·561	·680	·783	·853	·951	·920	·895	·866	·876	·735	·624
11	·619	·649	·705	·802	·868	·957	·901	·907	·879	·858	·723	·652
12	·615	·561	·702	·825	·836	·944	·899	·893	·862	·860	·697	·671
13	·568	·567	·722	·809	·858	·960	·900	·891	·874	·879	·681	·676
14	·628	·585	·705	·822	·855	·932	·900	·882	·884	·825	·643	·674
15	·604	·617	·689	·825	·894	·926	·895	·872	·888	·834	·692	·658
16	·577	·579	·695	·814	·855	·916	·896	·885	·882	·861	·691	·687
17	·546	·640	·658	·802	·848	·916	·911	·881	·889	·924	·714	·666
18	·559	·623	·696	·819	·883	·940	·903	·878	·874	·891	·658	·653
19	·584	·602	·721	·838	·878	·924	·904	·879	·863	·855	·650	·615
20	·583	·595	·764	·820	·864	·920	·902	·882	·869	·840	·690	·654
21	·605	·557	·769	·834	·858	·916	·891	·871	·866	·835	·707	·635
22	·587	·607	·771	·853	·863	·928	·904	·873	·874	·828	·692	·641
23	·579	·578	·751	·831	·870	·929	·905	·875	·867	·853	·659	·599
24	·561	·640	·736	·828	[·870]	·922	·913	·873	·870	·827	·660	·612
25	·570	·631	·717	·828	·871	·929	·902	·852	·871	·772	·673	[·590]
26	·582	·656	·754	·822	·891	·929	·893	·855	·847	·787	·674	·569
27	·617	·708	·759	·852	·890	·921	·897	·866	·851	·825	·645	·559
28	·636	·677	·747	·853	·899	·926	·890	·870	·874	·785	·659	·596
29	·622		·724	·839	·914	·926	·891	·858	·884	·752	·654	·621
30	·570		·764	·853	·893	·917	·897	·869	·871	·757	·677	·615
31	·528		·771		·893		·898	·875		·734		·595

The numbers enclosed within brackets, thus [ ], are interpolated from the means of the preceding and following days; they occur on days which have been regular holidays throughout the period.

TABLE 37.

SHOWING the NORMAL PRESSURE of VAPOUR for each Day of the Typical Year, derived from the Numbers in Table 36.

Date.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
1	·589	·572	·643	·759	·858	·912	·915	·894	·864	·875	·748	·670
2	·590	·571	·649	·763	·860	·916	·914	·893	·864	·876	·742	·668
3	·591	·571	·654	·766	·861	·921	·913	·893	·864	·877	·736	·665
4	·593	·570	·659	·770	·863	·925	·912	·894	·864	·877	·731	·664
5	·594	·568	·663	·774	·864	·928	·910	·894	·865	·877	·725	·665
6	·594	·566	·666	·779	·864	·931	·909	·893	·866	·876	·719	·665
7	·593	·567	·668	·783	·865	·934	·907	·893	·866	·875	·714	·666
8	·592	·569	·670	·787	·866	·935	·906	·892	·867	·873	·710	·665
9	·589	·572	·673	·791	·866	·935	·905	·890	·868	·872	·706	·664
10	·586	·575	·676	·795	·866	·935	·904	·890	·869	·872	·702	·661
11	·582	·577	·680	·799	·865	·935	·903	·889	·869	·871	·697	·658
12	·581	·580	·683	·802	·864	·935	·903	·888	·869	·870	·693	·654
13	·583	·583	·693	·806	·863	·935	·902	·886	·869	·868	·690	·652
14	·586	·586	·700	·810	·861	·934	·902	·885	·870	·865	·689	·650
15	·588	·589	·706	·813	·861	·933	·902	·883	·870	·862	·688	·649
16	·588	·593	·711	·816	·861	·932	·901	·882	·871	·858	·686	·647
17	·586	·596	·715	·819	·862	·931	·901	·880	·872	·854	·684	·645
18	·584	·600	·719	·821	·864	·929	·900	·878	·872	·849	·681	·642
19	·583	·605	·722	·823	·866	·928	·900	·875	·871	·844	·678	·638
20	·583	·610	·725	·825	·868	·926	·899	·873	·870	·839	·675	·632
21	·584	·616	·727	·827	·871	·925	·899	·871	·870	·835	·673	·627
22	·584	·620	·730	·829	·874	·923	·899	·870	·870	·829	·673	·623
23	·583	·623	·734	·832	·876	·923	·898	·869	·869	·822	·673	·619
24	·582	·625	·739	·835	·879	·922	·898	·869	·869	·814	·673	·615
25	·582	·626	·743	·839	·882	·922	·897	·868	·870	·805	·674	·612
26	·582	·628	·747	·843	·886	·921	·897	·868	·870	·796	·676	·610
27	·582	·632	·750	·847	·890	·920	·896	·867	·871	·788	·677	·609
28	·581	·637	·751	·851	·894	·919	·896	·867	·872	·781	·676	·605
29	·578		·752	·854	·898	·918	·896	·866	·873	·774	·674	·600
30	·575		·754	·856	·903	·916	·895	·865	·874	·765	·672	·595
31	·573		·756		·907		·895	·864		·756		·591
Monthly means	·585	·594	·705	·810	·872	·927	·902	·880	·869	·842	·694	·640

The means and normals of Tables 36 and 37 are curved in fig. 4, the former in black and the latter in red. We reserve our remarks upon them till after the diurnal variation of vapour pressure has been considered.

78. *Diurnal variation.*—In Table 38 is shown, for each month, for the summer and winter half years, and for the whole year, the excess of the vapour pressure at each hour of the day above the mean vapour pressure of the 24 hours in the respective months and in the whole year.

TABLE 38.

HOURLY EXCESSES of PRESSURE of VAPOUR.

Hours.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	April to Sept.	Oct. to March.	Year.
0	·000	−·003	+·008	+·003	−·005	−·009	−·009	−·011	−·013	−·011	+·013	+·004	−·007	+·003	−·002
1	−·003	−·004	+·009	−·001	−·009	−·012	−·014	−·014	−·016	−·016	+·004	·000	−·010	−·001	−·006
2	−·012	−·004	+·009	−·007	−·014	−·010	−·016	−·014	−·016	−·017	−·008	−·006	−·012	−·005	−·009
3	−·020	−·012	+·003	−·010	−·017	−·015	−·018	−·017	−·019	−·021	−·016	−·013	−·016	−·013	−·014
4	−·033	−·016	−·005	−·020	−·021	−·019	−·019	−·020	−·018	−·028	−·025	−·019	−·019	−·020	−·020
5	−·043	−·029	−·014	−·025	−·023	−·021	−·021	−·021	−·018	−·030	−·034	−·031	−·021	−·030	−·025
6	−·049	−·045	−·027	−·026	−·020	−·018	−·018	−·018	−·017	−·032	−·039	−·039	−·019	−·038	−·028
7	−·052	−·045	−·026	−·015	−·012	−·012	−·009	−·009	−·004	−·013	−·030	−·031	−·010	−·032	−·021
8	−·040	−·041	−·021	−·013	−·009	−·004	+·002	+·002	+·008	−·005	−·031	−·027	−·002	−·027	−·014
9	−·037	−·041	−·027	−·013	−·005	+·008	+·011	+·012	+·022	−·001	−·035	−·034	+·006	−·028	−·011
10	−·035	−·036	−·021	−·004	−·005	+·012	+·017	+·024	+·027	−·002	−·042	−·039	+·012	−·028	−·008
11	−·036	−·034	+·001	+·006	−·002	+·014	+·025	+·027	+·034	−·003	−·058	−·042	+·018	−·028	−·005
12	−·018	−·013	+·008	+·012	+·006	+·020	+·027	+·029	+·034	−·001	−·062	−·044	+·022	−·026	−·002
13	+·001	+·018	+·020	+·017	+·011	+·023	+·032	+·032	+·032	+·011	−·034	−·026	+·025	−·001	+·012
14	+·031	+·039	+·024	+·019	+·016	+·025	+·026	+·027	+·029	+·025	+·001	+·006	+·024	+·022	+·023
15	+·047	+·051	+·020	+·013	+·019	+·024	+·021	+·017	+·021	+·030	+·031	+·023	+·020	+·034	+·027
16	+·056	+·049	+·013	+·011	+·017	+·017	+·012	+·011	+·009	+·032	+·052	+·039	+·013	+·041	+·027
17	+·052	+·042	+·004	+·008	+·017	+·008	·000	−·001	−·005	+·023	+·055	+·046	+·005	+·038	+·021
18	+·051	+·037	+·001	+·002	+·013	+·002	−·007	−·006	−·013	+·019	+·062	+·053	−·001	+·038	+·018
19	+·050	+·032	·000	+·001	+·010	−·006	−·009	−·012	−·014	+·019	+·062	+·057	−·005	+·037	+·016
20	+·045	+·025	+·002	+·005	+·010	−·006	−·009	−·012	−·014	+·017	+·061	+·055	−·004	+·035	+·015
21	+·033	+·021	+·007	+·009	+·009	−·006	−·012	−·011	−·014	+·009	+·041	+·039	−·004	+·026	+·011
22	+·016	+·008	+·007	+·009	+·008	−·006	−·010	−·012	−·015	−·003	+·019	+·016	−·004	+·011	+·004
23	−·001	−·001	+·007	+·009	+·003	−·008	−·010	−·011	−·013	−·013	+·009	+·003	−·004	+·001	−·002

The curves corresponding to these variations form the black ink figures numbered from 54 to 68.

79. The pressure of vapour is nearly proportional to the quantity of vapour present in a constant volume of air, and may be taken to represent that quantity, or, in other words, the degree of moistness of the air. We shall see from the consideration of figs. 54 to 68, as well as of fig. 4, that the moistness of the air at Bombay is influenced chiefly by the direction of the prevalent wind—winds from the seaward bringing air highly charged with vapour, whilst land winds bring relatively dry air. But for the four months June to September the wind blows almost continuously from the seaward, with an average velocity of 16·5 miles per hour. During these months we may therefore regard the diurnal changes observed at Bombay, as pertaining also to the air over the ocean surface to westward of Bombay, which will thus be represented by the curves of diurnal variation of vapour pressure forming figs. 59 to 62. These curves are, as we should expect, similar in character to the temperature variations; rising from about sunrise till near the time of maximum temperature, then falling to the extent of about four-fifths of the preceding rise by about the time of sunset, and thenceforward falling very slowly till about sunrise again. As there

is reason to believe that the maximum temperature at sea is under otherwise like conditions in advance of the maximum over land,* we should expect the maximum vapour pressure at Bombay to be somewhat in advance of the maximum temperature which is influenced by the land, and so the curves show it to be. Thus the diurnal variation of vapour pressure in the months June to September—the average range of which is only ·051 inch—is sufficiently explained by the diurnal increase of temperature over the sea causing an increased capacity in the air to absorb vapour and consequent evaporation from the sea; by a reverse action producing deposition of vapour on the surface of the sea, when the temperature is falling, and by loss, due to continued upward diffusion, caused by agitation of the air, which is no longer counterbalanced by as great accessions from below. As we recede from these months, either onward or backward, the diurnal range increases, in November attaining ·124 inch; and correspondence with the temperature variation is entirely obliterated by the influence of the land and sea breezes.

80. The normal wind never blows at any season from the south-east quadrant in which lies the coast line to southward of Bombay: in separating winds into land and sea winds we need therefore only consider the direction of the coast line to northward, which is about N. 8° W. We have adopted N. 7° 49′ W., and drawing such a line with blue ink, through the zero point of each of the diurnal wind curves (to be described hereafter) of figs. 103 to 109 for the months October to April, we have measured for each hour the component velocities of the wind in a direction perpendicular to that line, or from the direction N. 82° 11′ E., and taken these as the velocities of the wind from landward. The points of intersection of the coast line, as we will call it, with the wind curves, mark the hours at which the wind of the typical day of each month ceases to blow from seaward, and begins to blow from landward, and *vice versâ*. These hours are shown in the following table, together with the number of hours during which in the typical day of each month the wind blew from landward, and the maximum velocity and total movement of that wind.

TABLE 39.

Months	October.	November.	December.	January.	February.	March.	April.
Wind from landward till - hours	11	12¼	12	11¼	11	10	8½
Wind from seaward till - hours	22	21	21½	22¼	1	4	4½
Wind from landward. Number of hours - -	13	15¼	14½	13	10	6	4
Wind from landward. Maximum velocity from landward in miles per hour -	5·36	9·50	7·91	5·71	5·28	3·39	1·61
Wind from landward. Total movement from landward in miles - -	37·40	88·59	68·33	40·23	27·60	12·74	3·98

On the typical day of each of the remaining months, May to September, the wind is from seaward all day long; but the exact dates between which the normal wind is all day from seaward are 27th April and 26th September.

* For example, in the Meteorological Committee's Square 3 of the North Atlantic the average time of the daily maximum temperature of the air is 1h. 2m. p.m., which would undoubtedly be an early average time on land.

81. With the aid of the numbers given in this table we are in a position to continue our examination of the curves of diurnal variation of pressure of vapour. About noon there is a sudden upward movement in the curves for October to December, and in these months the wind goes over to seaward at 11 hours, 12¼ hours, and 12 hours respectively; in January and February the sudden upward movement on the curves commences at 11 hours, and the wind changes to seaward at 11¼ hours and 11 hours; and in March and April the curve movement is at 10 hours and 9 hours, and the respective wind changes at 10 hours and 8½ hours. In every case the sea wind rapidly increases in velocity, and the accessions of vapour are consequently quickly perceptible; but after the change to landward the velocity from landward grows very slowly, and it is generally some hours before air that had been subjected to the drying influence of the land reaches Bombay in its return to seaward. The reason of this is that from an azimuth of about N. 25° E. round through east to seaward the waters of the harbour occupy the circuit through a radius of eight or nine miles; whilst from nearly the same azimuth—seeing that the narrow promontory of Colába subtends but a small angle—the waters of Back Bay occupy the circuit in the opposite direction through a radius of two to four miles; hence there is a period of relative constancy of vapour pressure lasting from about the time of change of wind till a few miles of air have blown over from landward. In October the change of wind occurs at 22 hours, and the period of constancy lasts from 23 hours to 2 hours, at which hours respectively only 0·3 and 4·1 miles of air, measured at right angles to the coast line, have passed over Bombay; or otherwise stated, air that comes from a distance of more than 4·1 miles to landward of the coast line and about 12 miles to northward along that line has become sufficiently dried, either by deposition of dew or formation of mist or clouds, to cause a sensible diminution of its vapour pressure. In November the wind comes from landward after 21 hours, and the period of constancy is from 23 to 0 hours, and the aggregate movements from landward at the latter hours are 3·2 and 6·4 miles. In December the numbers are—change of wind, 21½ hours; period of constancy, 23 to 1 hours; and aggregates, 1·1 and 6·2 miles. In January they are—change of wind, 22¼ hours; period of constancy, 23 to 1 hours; aggregate movement, 0·2 and 2·2 miles. In February we have change of wind at 1 hour; period of constancy from 23 to 2 hours; aggregate movements from seaward after 23 hours 0·5 mile, and from landward up to two hours 0·5 mile. This is the only month when the rate of diminution of velocity from seaward is slow near the time of change, and accordingly the period of constancy begins before the change of wind. In March and April the total movements of the wind from landward, in the whole day (12·7 and 4·0 miles respectively) are so small that—as in the month of May, when only abnormal winds blow from landward—the range of the diurnal variation of vapour pressure has become nearly a sea range, and its character, though still distinctly affected at the commencement of the sea breeze in March and April, has very markedly deviated from that of the months November to February, and approached that of the simple temperature variation. We now see that in the months October to February the great movement in the curve of diurnal variation, which commences suddenly about 11 or 12 hours, and ends suddenly about 23 hours, is very approximately contemporaneous with the sea breeze. At the commencement of the sea breeze the air to seaward has but recently been blown over from the land, and will retain for a time some of the dryness

it had acquired in its progress over land, the portions near the coast possessing much of it, and those further out to sea becoming gradually more and more moist. As these portions in turn pass over Bombay in their landward course, the vapour pressure rapidly rises, with a tendency to acquire that which prevails over the sea at the time; and since this latter condition is not reached till after the diurnal vapour pressure of the sea has passed its maximum, it is the highest vapour pressure that is attained; and it is attained sooner or later, according as the quantities of air that have, during the preceding land breeze, been blown over the sea are smaller or greater, and as the sea breeze is strong or weak in its early hours; for in November and December enough air has passed Bombay, during the land breeze, to cover a strip of the sea along the coast of 88·6 and 68·3 miles in breadth respectively, and the maximum vapour pressure is not reached till 18 hours; whilst in January and February, when the breadths of the strips of sea along the coast covered by air from the land are only 40·2 and 27·6 miles respectively, and when the velocity from seaward of the early sea breeze is greater than in November or December, the maximum vapour pressure is attained at 16 and 15 hours respectively. If there were no other influence in operation we should expect the vapour pressure, after reaching its maximum, to remain nearly constant—subject only to the slight fall due to the proper sea variation—until the commencement of the land breeze; and in the months November to January, periods of comparative constancy, varying in duration from two to four hours, do follow the attainment of the maximum; but for a reason which will now be described these periods are terminated and a rapid fall of vapour pressure takes place for three hours or more before the cessation of the sea breeze.

82. The anti-current of the land and sea breeze theory,* which, as complementary to the sea breeze below, has flowed over aloft to seaward, must in part, either itself or an equivalent body of other elevated and relatively dry air, find its way back landward by mingling with and taking the place of the lower air; thus the lower air being mixed with comparatively dry air in greater and greater proportions becomes gradually less moist. In the month of February it is probable that this influence prevents the maximum vapour pressure at sea from being fully attained at Bombay, for the fall commences with vigour very soon after the actual maximum is reached. In all the months from October to May the curves exhibit an interruption, for some hours after sunrise, to the fall of vapour pressure which we have attributed to the land breeze. This is probably caused by the reabsorption, after sunrise, of the dew, or dew and mist, which have been formed during the night at no great distance from the coast line; for we find that when the aggregate movement of the air to seaward, during the interval between sunrise and the commencement of the sea breeze, is considerable the fall of vapour pressure is soon resumed, the locally-formed vapour which causes the interruption being quickly carried away to sea. Thus in November the aggregate movement of the air to seaward from 6 to 8 hours is 18·2 miles with a further movement of 25·9 miles later, and the fall of vapour pressure is resumed before 8 hours; and in December the corresponding aggregate movements are 14·5 and 21·7 miles, and the fall is resumed at 8 hours; whilst the aggregate movements between 6 and 8 hours in the other

* This theory will be referred to at length when we come to consider the wind directly.

months never exceeding 10 miles, the fall is not resumed at all, though the early morning rise is arrested two or three hours before the commencement of the sea breeze. During these two or three hours we must suppose that the body of air which last reaches Bombay from landward has on its track gained as much vapour by evaporation as the day advances as that which first reached had in excess of it from being nearer to the coast, a supposition which is not unreasonable, seeing that for part of the time, and in all the months except May, the track of the air in its later stages, before reaching Colába, skirts the harbour. We have here assumed, as scarcely needing express statement, that, up to the limit of a normal day's motion, the further the progress landward of a body of air, the drier it becomes. At 6 a.m. on the typical day of each of the months October to April, taken in order, the bodies of air that will just reach Bombay and then return to landward are at the respective distances to landward—20·9, 44·1, 36·2, 23·8, 20·2, 10·2, and 3·2 miles.* Those of November and December which come from the greatest distance are, we have seen, those which, on reaching Colába, most reduce the vapour pressure.

83. The explanations that have already been given of the principal features of the diurnal variation of vapour pressure, attribute the corresponding changes to local causes depending chiefly on the variations of the east and west component of the wind. We have now to call attention to smaller features of some of the curves of vapour pressure which seem to be related to the variations of the north and south component of the wind. These latter variations are represented by the curves of figs. 69 to 83; they have a very small range in the monsoon months, but in the dry months the diurnal difference between the velocities per hour of the weakest and strongest north components of the wind becomes as large as 8·0 miles. In the months November to February the maximum occurs at 18 or 19 hours, and about these hours we observe a flattening of the upward convexity of the vapour pressure curves, which constitutes such an interruption to the free and smooth flow of the curves as implies the action of a separate depressing influence distinct from the cause of the general movement. Such influences we have explained the acquirement of the maximum sea vapour pressure and the return of the anti-current of the sea breeze to be, and if we had to judge by these months alone, we should be unable to give any reason for not attributing the interruption wholly to them; but at the same and two preceding hours we find depressions in the vapour pressure curves of March and April, which correspond to maxima of the north and south wind variation at about 16 hours, and are followed by upward inflexions corresponding in time to downward inflexions of the north and south wind curves, the middle hour of which is about 23; and in October and May there are tendencies — not well developed — to similar correspondences. Now the two contributory influences which affect the 18 hours' depression offer no explanation of the slight but distinct and systematic elevation which follows it; whilst it is in perfect accord with general reasoning on meteorological questions to attribute in the northern hemisphere, and the sun being considerably to southward of the station, to north winds coming from cooler and therefore generally drier

* The assumption involved here that the movement of the air, within a circuit of a few miles of Bombay, is the same as at Bombay, both in direction and velocity, is doubtless approximately correct, and it is the only practicable one.

regions a dry condition, and to south winds coming from warmer and therefore damper regions a moist condition; and this especially if a great continent lies to northward and a great ocean to southward of the station, as is the case throughout India; and as strong winds bring the conditions of distant regions more quickly and in greater measure than light ones, so a stronger north wind than a given average will, relatively to it, depress the vapour pressure, whilst a weaker one will relatively raise the vapour pressure. That such depressions and elevations do in fact accompany respectively the maximum and minimum north components of the wind at Colába, we think the inflexions of the curves that we have just spoken of afford evidence.

84. *Annual variation continued.*—Let us now return to the variation of vapour pressure from day to day, as shown by the red curve of fig. 4. From the 1st January to the 6th February, on which last day the minimum (0·566 inch) of the year occurs, the normal vapour pressure is nearly constant, ranging only from 0·566 to 0·594: this period is coincident with a period of nearly constant temperature, in which also the minimum of the year occurs on the 6th February. At this time we have combining to produce the low vapour pressure, (1) the fact of the sun's declination being far to southward of the parallel in which Bombay lies, causing a low temperature—by reason of a low radiation from the sun—and consequent low capacity of the air for vapour; (2) as an influence of some degree of permanency, the normal wind from N.N.W. with a north component nearly at its maximum of the year throughout the period, bringing cold and relatively dry air from the land in that direction, and diminishing the air's capacity still further; and (3), as a local influence, the diurnal variation of the wind, such that for half the day the wind blows from landward, again bringing relatively dry air. These influences we must suppose to have a great ascendency over the contrary local one, arising from the fact of the diurnal sea breezes prevailing for the remaining half of the day; and this the small range (0·106 inch) of the diurnal variation compared with the annual range (0·369 inch) gives us good reason for doing. From 6th February to 6th May there is a gradual and steady rise both of vapour pressure and temperature, which stand in the relation to each other of effect and cause; but again the effect is contributed to by the gradual diminution, after the first month, of the normal north component of the wind, and by the increasing proportions of the day during which the wind is from seaward, the numbers of hours per day during which, on the typical day of the months February, March, and April, the wind is from seaward being 14, 18, and 20 respectively. Between 6th and 20th May there is a temporary and almost complete arrestation of the rise of temperature and a slight depression of the vapour pressure, which latter phenomenon may be in part a consequence of the former. The rise of vapour pressure is resumed, and before the end of May acquires a greater rate than at any other part of the year. The pressure has reached the maximum of the year (0·935 inch) on the 8th June, at which point it remains till the 13th; the interval nearly corresponds to the average time of the Elephanta storms, which constitute what is usually called the break of the monsoon, and which are accompanied by thunder and lightning and heavy rain. The maximum vapour pressure is followed by a gradual fall till the 24th August, when it has become 0·870 inch, and then it remains nearly constant for a month. The movements of the

thermometer differ from these in that the maximum is reached eight days earlier and the commencement of the period of constant temperature 40 days earlier; but the rapid rise of vapour pressure after the 20th May is doubtless attributable to the increased capacity of the air caused by the corresponding rise of temperature, and so also is the slight rise at the beginning of October to the corresponding rise of temperature; but in the former case the continued growth of the south component of the wind combines, by bringing damper air from further south, to produce the result, whilst in the latter the opposite condition opposes its production. It is worthy of notice that in the former case the one contributing cause, the temperature variation, reaches its maximum at the end of May, whilst the other, the variation of the north component of the wind, does not reach its minimum till the 18th June, and consequently the maximum of vapour pressure is not coincident with that of temperature, but is drawn towards the minimum of north wind, and occurs on the 8th–13th June. After the small rise, which has its maximum on 3rd–5th October, the vapour pressure curve descends slowly at first, but with gradually increasing rapidity—producing a fall of ·110 inch between 21st October and 5th November—until on 21st November it has become 0·673 inch; it then varies but slightly till 9th December, when the fall is resumed and continued till the end of the year; and the temperature movements are almost exactly similar to these. We have therefore the corresponding fall of temperature as a contributory to the first-mentioned rapid fall; we have also an increase of the normal east component of the wind bringing more dry air from the land; and the wind, which in September had been all day from seaward, blowing for 14 of the 24 hours from landward. For the succeeding nearly stationary period we have correspondence in a nearly stationary temperature, and in a constant wind which had previously been receiving daily increments from the north-east, and also in that the number of hours during which the wind blows from landward has ceased to increase, the maximum number having been passed in November. Lastly, the remaining fall of vapour pressure is accompanied by a fall of temperature, and rise of the north component of the wind.

We have already stated that the period during which the normal wind blows all day long from seaward is 27th April to 26th September. For this reason, but not for this alone, the normal daily vapour pressure of the same period never falls below 0·847 inch. Another reason is that it is the summer season, during which the maximum temperature occurs, and about the time of this maximum the curve of vapour pressure exhibits a prominent elevation above its general course for the rest of the period. But the chief cause of the long continued high vapour pressure is that heavy rains prevail throughout the months June to September and keep the soil and its clothing vegetation almost perpetually wet, and much of the lowlands swampy; consequently the surface air is nearly always skimming moist surfaces, appropriating the moisture by evaporation up to the limit of its capacity, and then mingling with the strata above it, thus restoring some of the vapour that the air loses, in its progress landward and overland, by the formation of rain. And besides, the principal drying influence which operates during the winter months—viz., the cooling of the ground by radiation at night and consequent deposition of vapour from the cooled air near it—is ineffective during the monsoon, because of the almost complete and perpetual cloudiness of the sky, the clouds and

damp air returning nearly as much heat to the ground by radiation as they receive from it.

85. *Variability.*—The maximum and minimum values of the pressure of vapour observed in each of the years from 1847 to 1872—first, at any moment; secondly, of daily means; and thirdly, of monthly means—are shown in Table 40, and they are also exhibited to the eye by means of the fig. 198 of Plate XXVII.

TABLE 40.

Year.	Individual Hours.								Daily Means.						Monthly Means.					
	Maximum.				Minimum.				Extreme range in Year.	Maximum.		Minimum.		Range in Year.	Maximum.		Minimum.		Range in Year.
	Pressure of Vapour.	Time of Occurrence.			Pressure of Vapour.	Time of Occurrence.				Pressure of Vapour.	Date of Occurrence.	Pressure of Vapour.	Date of Occurrence.		Pressure of Vapour.	Month.	Pressure of Vapour.	Month.	
	inch.	hr.	day.	mth.	inch.	hr.	day.	mth.	inch.	inch.	day. mth.	inch.	day. mth.	inch.	inch.		inch.		inch.
1847	1·099	13	4	6	·189	4	3	2	·910	·985	31 5	·259	2 2	·726	·934	6	·606	2	·328
1848	1·046	12	22	6	·303	3	4	2	·743	·987	21 6	·330	6 2	·657	·918	6	·629	2	·289
1849	1·214	14	11	6	·280	9	17	1	·934	1·060	12 6	·351	16 1	·709	·969	6	·588	1	·381
1850	1·076	15	15	6	·270	9	21	1	·806	·983	27 5	·392	1 2	·591	·942	6	·566	1	·376
1851	1·080	14	13	6	·236	6	15	1	·794	·988	11 6	·348	14 1	·640	·929	6	·555	1	·374
1852	1·069	15	19	10	·265	6	17	1	·804	·961	1 7	·369	17 1	·592	·920	6	·508	1	·412
1853	1·028	12	9	6	·247	9	22	1	·781	·974	10 6	·353	22 1	·621	·934	6	·511	1	·423
1854	1·124	11	8	6	·198	9	2	2	·926	1·025	7 6	·337	2 2	·688	·946	6	·557	2	·389
1855	1·110	16	11	6	·297	7	18	1	·813	1·002	5 5	·439	18 1	·563	·947	6	·596	1	·351
1856	1·076	13	28	6	·300	12	9	12	·776	·977	12 6	·425	9 12	·552	·933	6	·625	2	·308
1857	1·125	11	2	5	·321	13	10	12	·804	1·067	2 5	·475	10 12	·592	·933	5	·566	12	·367
1858	1·139	14	30	4	·360	22	21	1	·779	1·044	22 5	·479	27 1	·565	·968	5	·625	1	·343
1859	1·155	14	14	7	·369	4	12	2	·786	1·040	14 7	·439	3 12	·601	·957	7	·608	12	·349
1860	1·088	11	15	6	·299	8	24	1	·789	1·019	15 6	·405	24 1	·614	·956	6	·562	1	·394
1861	1·066	11	21	5	·260	14	25	1	·806	·982	20 5	·402	24 1	·580	·921	6	·565	1	·356
1862	1·055	21	2	6	·304	11	18	1	·751	·983	8 7	·423	17 1	·560	·934	7	·553	1	·381
1863	1·000	12	17	6	·267	14	3	12	·733	·927	23 4	·390	3 12	·537	·902	6	·577	2	·325
1864	1·040	19	29	9	·219	8	25	2	·821	·948	30 9	·359	16 1	·589	·900	6	·484	1	·416
1865	1·107	18	6	6	·353	8	13	2	·754	·989	16 6	·488	28 12	·501	·930	6	·607	2	·323
1866	1·089	17	9	10	·235	5	12	2	·854	·978	11 6	·336	9 2	·642	·932	6	·545	2	·387
1867	1·046	15	14	6	·282	12	6	2	·764	·987	11 6	·428	4 2	·559	·947	6	·560	2	·387
1868	1·091	18	2	6	·128	10	6	3	·963	1·023	1 6	·335	6 3	·688	·953	6	·583	1	·370
1869	1·052	12	28	6	·272	12	8	12	·780	·992	28 6	·433	10 2	·559	·930	6	·608		·322
1870	1·044	17	15	9	·244	12	21	2	·800	·976	13 6	·432	20 1	·544	·915	6	·566		·349
1871	1·051	14	16	10	·346	12	3	3	·705	·959	9 6	·474	4 3	·485	·915	6	·632	1	·283
1872	1·091	14	12	6	·217	10	16	1	·874	·996	10 6	·348	25 1	·648	·925	6	·515	1	·410

In Table 41 are given the maximum and minimum values of the pressure of vapour observed in each month of any of the 26 years, and the same numbers are represented by the lines on fig. 199.

TABLE 41.

Month.	Individual Hours.					Daily Means.				
	Maximum.		Minimum.		Extreme Range in Month.	Maximum.		Minimum.		Range in Month.
	Pressure of Vapour.	Time of Occurrence.	Pressure of Vapour.	Time of Occurrence.		Pressure of Vapour.	Date of Occurrence.	Pressure of Vapour.	Date of Occurrence.	
	inch.	hr. day. yr.	inch.	hr. day. yr.	inch.	inch.	date. year.	inch.	date. year.	inch.
January	·936	13 6 1859	·239	3 25 1864	·697	·825	24 1847	·348	25 1872	·477
February	·958	14 24 1857	·189	4 3 1847	·769	·823	21 1857	·259	2 1847	·564
March	1·017	12 26 1858	·128	10 6 1868	·889	·945	26 1858	·335	6 1868	·610
April	1·139	14 30 1858	·398	3 25 1850	·741	·978	29 1858	·608	3 1852	·370
May	1·125	11 2 1857	·617	9 3 1872	·508	1·067	2 1857	·735	4 1852	·332
June	1·216	15 11 1849	·738	20 22 1865	·478	1·060	12 1849	·801	6 1857	·259
July	1·157	6 15 1859	·718	17 18 1867	·439	1·040	14 1859	·841	28 1853	·199
August	1·053	14 4 1858	·736	16 27 1847	·317	·988	24 1849	·795	31 1855	·193
September	1·043	20 29 1864	·581	8 22 1865	·462	·959	15 1870	·704	19 1851	·255
October	1·089	17 9 1866	·435	12 25 1872	·654	1·008	4 1858	·623	21 1850	·385
November	1·056	11 4 1850	·318	12 27 1869	·738	·932	3 1850	·461	18 1869	·471
December	·913	7 14 1856	·267	14 3 1863	·646	·856	2 1869	·425	9 1856	·431

In connection with the decennial variation of vapour pressure, referred to in paragraph 76, it is worthy of note that the maximum daily means in the above table occur for every month of the year, in years whose numbers end with one of the figures 7, 8, 9, or 0, and more than half the minimum daily means in the years whose numbers end with one of the figures 1, 2, 3, 5, or 6.

86. *Capacity of the air to receive more vapour.*—The variations of the pressure of vapour tell us very nearly the variations in the quantity of vapour contained in a given volume of air; but they do not tell us what power the air possesses of absorbing more vapour, because this power depends not only upon the quantity of vapour present, but upon the full capacity of the air to absorb vapour, and this in turn depends upon the temperature, increasing as the temperature increases; and so rapid is this increase that within the range of the air temperature at Colába the capacity quadruples itself. The quantity called by meteorologists the relative humidity of the air is the proportion of the vapour actually present to the maximum quantity which the air could contain at the existing temperature; and it is used as an arbitrary measure of the readiness of the air to change its condition of humidity, either to absorb more vapour or to deposit, by condensation on cooling, some of that which it possesses. It is possible that at Colába the same number may represent the relative humidity when the temperatures are different, and yet the quantity of vapour which the air has power to absorb without change of temperature may in the one case be four times as great as in the other. It seems to us that some measure which has reference to one invariable material unit is much to be preferred for scientific purposes to this of relative humidity, and accordingly we have chosen the additional vapour pressure that the air has capacity to receive without change of

temperature as such a measure; a quantity that is proportional to, but more readily obtained than, the one sometimes used as the number of grains of vapour in a cubic foot of air required to produce saturation.

87. The average additional capacity of the seven years 1866 to 1872 is 0·223 inch, those of the 12 months taken in order beginning with January are 0·243, 0·259, 0·252, 0·263, 0·296, 0·211, 0·133, 0·130, 0·145, 0·194, 0·284, and 0·266. Instead of drawing an independent curve of additional capacity for every day in the year, we have drawn one (fig. 3) representing the total capacity corresponding to the normal temperature of each day, on the same form as the curve of annual variation of pressure of vapour; the length of the interval between the extremities of the ordinates of the two curves for a given day thus corresponds to the additional capacity, and the variation of it from day to day and month to month can be readily apprehended. As well from the parallelism of the two curves as from the monthly means given above, it will be seen that the normal additional capacity undergoes scarcely any change during the period from December to April; the months cutting off this period at both ends from the monsoon—May and November—have both somewhat larger values; from the beginning of June the additional capacity diminishes rapidly till after the first maximum of normal rainfall; during the following fortnight—of moderated rainfall—it is nearly constant, and then again rapidly diminishes till immediately after the second maximum of normal rainfall, in the middle of July, when it reaches the minimum of the year, 0·103 inch, the normal vapour pressure at the same time being 0·900 inch. From this time, the 20th July, it slightly increases for about a month, and then remains constant till the beginning of October; thenceforward it increases at a nearly uniform rate till the beginning of November. The notable features in the variation of this element are, as might have been predicted, its low values during the rainy season, and high values during the dry season; from July to September the average is 0·136 inch, and from November to May 0·266; its approach to constancy during the latter period is also remarkable.

88. The diurnal variation of the additional capacity of the air being made up of two parts, the first of which is the reverse of the diurnal variation of vapour pressure, and the second the diurnal variations of the total capacity due to variation of temperature, it has been curved in violet ink on the same form (of figs. 54 to 68) with the curves of diurnal variation of vapour pressure; but in order that the magnitudes of the two parts should be exhibited by the same figures the upward ordinates are made to represent (contrary to the usual rule) defects of the additional capacity from the average of the day, and the downward ordinates excesses. Thus, if there were no diurnal variation of temperature, the two curves on each form would coincide, and the parts of the ordinates included between the loops formed by the two curves represent the additional capacity due to variation of temperature, being an excess if the violet curve is below the black one, a defect if above.

TABLE 42.

SHOWING for each MONTH, for the SUMMER and WINTER HALF YEARS, and for the WHOLE YEAR, the EXCESS of the additional CAPACITY of the AIR to receive VAPOUR at each hour of the day above its mean value for the 24 hours.

Hours.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	April to Sept.	Oct. to March.	Year.
0	−·083	−·085	−·093	−·093	−·090	−·055	−·021	−·022	−·037	−·073	−·109	−·088	−·050	−·088	−·070
1	−·090	−·095	−·102	−·099	−·097	−·049	−·026	−·025	−·044	−·077	−·112	−·095	−·057	−·096	−·075
2	−·093	−·105	−·111	−·105	−·102	−·062	−·024	−·031	−·047	−·085	−·111	−·098	−·062	−·103	−·081
3	−·095	−·112	−·116	−·115	−·106	−·060	−·029	−·035	−·050	−·088	−·112	−·102	−·064	−·106	−·085
4	−·092	−·115	−·123	−·118	−·113	−·063	−·031	−·035	−·058	−·090	−·111	−·104	−·068	−·107	−·088
5	−·092	−·112	−·125	−·125	−·114	−·068	−·032	−·037	−·058	−·097	−·111	−·099	−·072	−·108	−·092
6	−·093	−·106	−·125	−·127	−·114	−·064	−·035	−·040	−·062	−·101	−·114	−·102	−·071	−·108	−·092
7	−·090	−·101	−·104	−·081	−·062	−·046	−·028	−·036	−·059	−·089	−·098	−·102	−·051	−·100	−·078
8	−·053	−·045	−·037	−·014	−·007	−·018	−·016	−·022	−·039	−·047	−·041	−·057	−·018	−·047	−·036
9	+·004	+·015	+·034	+·046	+·035	+·007	−·001	−·005	−·017	−·007	+·016	+·001	+·012	+·010	+·009
10	+·061	+·073	+·083	+·077	+·078	+·040	+·014	+·009	+·005	+·039	+·081	+·057	+·038	+·066	+·052
11	+·118	+·135	+·106	+·109	+·119	+·062	+·027	+·031	+·033	+·090	+·159	+·114	+·062	+·121	+·091
12	+·163	+·166	+·137	+·145	+·145	+·079	+·042	+·046	+·057	+·144	+·232	+·183	+·084	+·178	+·131
13	+·186	+·168	+·154	+·164	+·169	+·096	+·052	+·054	+·081	+·163	+·253	+·221	+·100	+·192	+·150
14	+·176	+·165	+·161	+·174	+·177	+·098	+·051	+·062	+·091	+·168	+·237	+·214	+·109	+·187	+·151
15	+·160	+·153	+·162	+·175	+·166	+·095	+·048	+·062	+·096	+·163	+·196	+·197	+·105	+·171	+·143
16	+·128	+·137	+·147	+·146	+·138	+·082	+·043	+·050	+·093	+·134	+·133	+·149	+·093	+·139	+·117
17	+·051	+·088	+·113	+·103	+·088	+·052	+·024	+·034	+·065	+·071	+·032	+·049	+·060	+·069	+·065
18	−·005	+·009	+·035	+·024	+·017	+·013	+·007	+·009	+·025	+·011	−·026	−·010	+·016	+·003	+·010
19	−·033	−·021	−·003	−·017	−·037	−·009	−·005	−·001	+·006	−·021	−·056	−·039	−·008	−·027	−·018
20	−·045	−·032	−·020	−·042	−·059	−·023	−·011	−·008	−·004	−·039	−·077	−·058	−·023	−·047	−·033
21	−·055	−·047	−·044	−·063	−·072	−·034	−·015	−·012	−·017	−·051	−·082	−·066	−·033	−·059	−·045
22	−·062	−·059	−·059	−·076	−·082	−·041	−·020	−·017	−·023	−·058	−·088	−·075	−·043	−·068	−·054
23	−·069	−·069	−·080	−·086	−·084	−·043	−·020	−·022	−·031	−·064	−·096	−·079	−·047	−·075	−·061

89. The curves show at a glance that in every month the variation of additional capacity due to variation of temperature far outweighs the actual variation of vapour pressure, so that the interesting features of the vapour pressure curves that we have remarked upon are completely masked in the additional capacity curves. Remembering, however, that positive ordinates of the latter are marked downward, and positive ordinates of the former upward, the additional capacity curves of the months June to August—being of nearly similar form, except that they are inverted, to the vapour pressure curves—exhibit in another and more direct and exact form, the grounds for attributing the variations of vapour pressure in these months mainly to like variations of the capacity of the air to receive more vapour. We remark too that the extent of variation of additional capacity is, even in the most rainy months, July and August, about twice as great as the variation of vapour pressure, whilst in June it is nearly four times as great. The similarity of the two curves is most exact in June; in September the maximum of vapour pressure is reached by too rapid a rise and receded from by too slow a fall as compared with the corresponding additional capacity movements; and this departure from exact similarity grows more

marked as the time advances from June to September. A possible partial explanation of these departures is that it is in the lowest stratum of the air that the evaporation that takes place—especially on the rainless days of September—begins, and the transfer of a portion of the vapour formed in the morning, through the air intervening between the ground and a height of $4\frac{1}{2}$ feet, may, owing to its greater lightness than air, be more rapid than the transfer of air temperature, which must in the main follow a similar course; hence the more rapid rise of the vapour pressure curve in the early part of the day than fall of the additional capacity curve, which is mainly an inverse temperature curve.

Cloudiness.

90. The degree of cloudiness, in eighths of the whole sky, has been estimated at every hourly observation; and the means of these estimations are shown, for each month of the years 1847 to 1870, in the following table.

Table 43.

Extent of cloudy Sky.

Year.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov..	Dec.	Annual means.
1847	2·9	1·5	3·5	3·4	4·6	7·2	7·5	7·5	6·4	4·1	1·5	0·8	4·2
1848	0·4	0·2	0·7	2·7	3·3	5·6	6·2	6·6	4·0	2·9	1·8	1·4	3·0
1849	0·6	0·8	1·3	0·9	2·6	7·2	7·1	6·5	6·7	3·0	2·5	0·7	3·3
1850	0·7	0·5	1·6	1·2	2·0	6·2	7·1	6·8	5·5	4·8	1·3	1·9	3·3
1851	1·3	0·5	1·4	1·6	3·6	6·2	7·3	7·0	5·1	2·5	2·4	0·7	3·3
1852	0·7	1·5	1·3	1·9	2·8	6·4	6·7	6·8	6·1	2·6	1·3	2·3	3·4
1853	1·2	2·4	1·7	1·4	1·8	6·4	7·4	6·8	4·6	1·5	1·4	0·6	3·1
1854	2·4	0·6	0·6	2·0	3·4	6·4	7·8	7·2	5·9	4·7	3·6	2·5	3·9
1855	1·4	3·1	1·4	2·8	3·1	6·7	7·8	7·1	6·6	4·2	1·2	1·5	3·9
1856	2·4	2·1	1·9	1·2	4·1	6·6	7·7	7·0	5·6	2·8	1·4	1·4	3·7
1857	2·5	0·3	0·5	1·6	3·6	6·3	7·2	7·7	6·2	3·3	1·2	0·9	3·4
1858	0·9	0·9	1·5	2·5	5·0	5·4	6·7	7·2	5·6	2·8	1·4	2·2	3·5
1859	0·6	0·6	1·3	1·5	2·4	6·1	6·8	7·0	6·4	2·3	2·0	1·4	3·2
1860	0·5	1·8	1·0	2·3	2·8	6·2	7·0	6·6	5·9	4·5	1·4	1·4	3·4
1861	2·3	1·1	1·2	2·1	3·7	6·4	7·7	7·4	6·0	3·8	1·8	0·4	3·7
1862	1·3	0·9	0·6	2·5	3·5	6·1	7·4	7·2	6·9	5·1	3·2	0·6	3·8
1863	1·9	0·2	1·5	2·0	3·9	7·2	7·7	7·7	6·4	4·2	1·3	1·1	3·8
1864	3·2	1·4	2·2	2·2	3·5	6·8	7·6	7·5	6·1	2·5	3·5	2·1	4·0
1865	2·3	2·4	2·3	3·5	5·4	7·0	7·7	7·9	6·5	5·3	1·8	1·7	4·5
1866	0·9	0·7	1·2	1·1	2·8	5·9	7·5	7·4	5·0	3·8	0·6	0·9	3·1
1867	1·1	0·4	2·4	2·2	3·3	6·6	7·2	7·3	6·6	4·1	2·1	0·8	3·7
1868	0·8	1·5	1·1	1·5	2·5	7·1	7·0	7·2	5·8	3·2	1·8	1·4	3·4
1869	1·5	0·6	1·7	2·2	3·2	6·4	6·8	7·1	7·0	3·3	2·4	2·6	3·7
1870	1·8	0·9	2·8	1·5	4·4	6·5	7·8	7·2	6·3	5·1	2·2	1·5	4·0
Monthly means	1·5	1·1	1·5	2·0	3·4	6·5	7·3	7·2	6·0	3·6	1·9	1·4	3·6

The numbers in the last line tell us that from December to March clouds cover, in the average, only about a sixth of the whole extent of the sky, whilst in July and

August they cover nearly the whole of it; in June and September the cloudiness is about three-fourths; in May and October less than one-half; and in April and November about one-fourth. It is to cloudiness mainly, which is itself due to the prevalence of the west-south-west wind, that must be attributed the principal interruption that occurs during the monsoon months in the regular seasonal variations of temperature; for in these months the clouds stop the radiant heat of the sun, and prevent a great part of it from ever reaching the ground, whilst at the same time they themselves radiate heat, though in less degree, but more continuously, to the ground, thus moderating the daily rise and fall of temperature, but also decreasing the absolute temperature of the air near the earth's surface. The latter result is also contributed to by the consumption of radiant heat in producing evaporation simply, unattended by increase of the sensible heat of the soil.

91. The diurnal variation of cloudiness is very small, but it shows itself very distinctly in the mean for the 26 years 1847 to 1872. The absolute mean for this period is 3·6, and the excesses above it at the several hours as follows:—

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
−0·2	−0·1	0·0	−0·1	−0·1	+0·1	+0·4	+0·5	+0·4	+0·3	+0·1	0·0	−0·1	−0·1	0·0	0·0	0·0	+0·1	+0·2	−0·1	−0·4	−0·4	−0·3	−0·3

The principal maximum and minimum of cloudiness are at 7 hours and 20 or 21 hours respectively, and there is a subordinate maximum at 17 or 18 hours, and a subordinate minimum at 12 or 13 hours, with regular changes from maximum to minimum, and *vice versâ* in the intervals. The difference between the maximum and minimum is only about a ninth of the whole extent of the sky, although at times the tendency to a rapid development of cloud, about the times of sunrise and sunset, is very noticeable; and it is near these times that the two maxima occur, that near sunrise being the greatest, for the obvious reason that the vapour condensed during the night near the earth's surface is then being rapidly evaporated and lifted to a height at which it is recondensed by mixture with cool air already highly charged with vapour. The secondary minimum occurs soon after noon, when the sun's rays are being received, either by the vapour suspended in the air, or by the earth's surface, in greatest abundance, and when therefore the tendency to dissipation of visible vapour is strongest. It is possible that some of the rather sudden changes shown at the times of sunrise and sunset may be due to the kind of light by which the sky is seen; the light of day bringing strongly into view, and causing to be classed as cloud, regions which in the feeble light of night would appear only as a thin haze.

Temperature of the Ground.

92. Thermometers with their bulbs resting on, or sunk in, the ground have been observed for periods shown in the following statement:—

Thermometer laid on the ground, with the bulb in contact with it, and exposed to the air, from 1847 to 1859.

Bulb buried in the ground, one inch below the surface, from 1860 to 1872.
Ditto, six inches below the surface, from 1847 to 1859.
Ditto, nine inches below the surface, from 1860 to 1872.
Ditto, twenty inches below the surface, from 1848 (June) to 1872.
Ditto, five feet below the surface, from 1851 (February) to 1872.
Ditto, twelve feet below the surface, from 1851 (Feb.) to 1854 (Oct.).

The 6-inch and 12-foot thermometers were broken during the hurricane of 1st–2nd November 1854, and the latter was not restored.

93. Up to the year 1850 the thermometers on the ground, and six inches deep, were placed in the old thermometer shed; and from 1851 onwards all the ground thermometers were placed in the larger thermometer shed, which was brought into use at the beginning of 1851. It would appear from the records that a hole was dug in the middle of the shed, large enough and deep enough to accommodate all the thermometers, and was then filled with "soil composed of red earth and a portion of decomposed trap gravel," the thermometers being embedded in the soil with their bulbs at the proper depths. The same description of soil is said to have formed the bed of the six inches deep thermometer before 1851.

The first thermometer in contact with the ground was used till 8th February 1856. As compared with the observatory standard it had no error at 80° and only +0·4 at 114°, for which no correction has been applied. It was replaced for 10 days by a Newman's standard thermometer, and this again on 18th February 1856 by a thermometer with an error between 60° and 90° of +1°·8: the latter instrument was in use till 5th August 1858, and the correction (−1°·8) was applied. A third thermometer, of which no comparison with a standard is recorded, seems to have been observed lying on the ground till about the end of 1859, after which the observations were printed as of a thermometer with its bulb one inch deep, and the diurnal range is thereafter diminished about 2°·0. At the same time the observations with the six inches deep thermometer cease to be printed, and are substituted by observations of a nine inches deep thermometer, and the diurnal range diminishes by about 1°. It is probable therefore that the thermometers on the ground and six inches deep became respectively the one-inch and nine-inch thermometers of the period of 13 years following 1859, during which no change of instrument is recorded. The only change of the 6-inch thermometer was on the occasion of the breakage of the first one during the storm of 1st–2nd November 1854.

The parts of the deep thermometers—20-inch, 5-foot, and 12-foot—buried in the soil are enclosed in brass tubes; the errors of graduation both of these and of the 6-inch and 9-inch thermometers are unknown. The 20-inch thermometer was substituted by another of the same construction on 13th December 1861, but for observing the temperatures at five feet depth and 12 feet depth the same thermometers were used throughout.

94. *Annual means.*—The following table exhibits the annual mean values of the temperature of the air from three to five feet above the ground, of a thermometer laid on the ground, and of the soil at depths of one inch, six inches, nine inches, twenty inches, five feet, and twelve feet respectively.

TABLE 44.

YEAR.	Air 3 to 5 feet above Ground.	Thermometer on the Ground.	SOIL AT DEPTHS OF					
			1 inch.	6 inches.	9 inches.	20 inches.	5 feet.	12 feet.
1847	79·0	79·5		82·7				
1848	79·8	80·2		82·2				
1849	79·6	80·0		80·9		83·6		
1850	79·9	80·3		80·9		84·1		
1851	79·5	80·1		80·1		81·6	83·5*	83·1*
1852	80·2	80·6		80·6		81·7	83·6	82·5
1853	80·5	80·8		80·9		81·7	83·6	82·2
1854	80·6	81·0		81·2		82·2	83·9	81·8†
1855	80·7	81·0		80·7		81·7	83·6	
1856	80·5	80·6		80·9		82·0	84·0	
1857	79·9	80·1		80 2		80·9	83·0	
1858	80·1	80·1		80·3		80·8	82·5	
1859	80·2	79·9		80·6		81·2	82·9	
1860	80·0		79·6		81·1	82·2	83·6	
1861	79·3		79·0		81·0	82·2	83·9	
1862	80·6		80·3		81·6	84·0	84·2	
1863	79·8		79·5		80·7	83·8	84·0	
1864	79·9		79·7		80·7	83·2	83·6	
1865	81·0		81·0		82·0	84·2	84·5	
1866	78·3		79·3		80·0	82·5	83·3	
1867	78·8		79·7		80·1	82·1	83·2	
1868	79·1		80·1		80·4	82·2	83·4	
1869	79·9		80·8		81·2	82·8	83·7	
1870	79·0		80·0		80·6	82·5	83·7	
1871	80·1		81·0		81·5	83·0	83·8	
1872	78·9		79·8		80·4	82·2	83·1	
Means - - -	79·8	80·3	80·0	80·7	80·9	82·4	83·6	82·4
Years included in means - -	1847 to 1872	1847 to 1859	1860 to 1872	1849 to 1859	1860 to 1872	1849 to 1872	1851 to 1872	1851 to 1854

* These means are exclusive of the month of January.

† This mean is exclusive of the months of November and December.

95. These numbers are curved in figs. 236 to 243, but breaks in the continuity of the curves are made between 1850 and 1851, and between 1865 and 1866; in the first case, on account of the removal at the beginning of 1851 of the thermometers from the old to the new shed; and in the second case, on account of the introduction of the cage into the thermometer shed, and its acting to protect the soil from radiation from the roof of the shed. The effect of the latter change was to produce a very considerable fall in the readings of all the thermometers, but in the case of the air thermometer 0°·7 of the actual fall is due to correction for errors of graduation, first applied in 1866. A break of continuity is also introduced into the curve of the thermometer 20 inches deep, between 1861 and 1862, on account of the change of instrument in December 1861. Throughout the whole period from 1847 to 1872 the correspondence of movement of

the air thermometer, with that lying on the ground, or one inch deep, is remarkably close: so also is that of the 6-inch thermometer from 1851 to 1859, and that of the 9-inch thermometer throughout, with both the air thermometer and the one on the ground, or the one with bulb one inch deep. At the end of 1848 it seems probable that some unrecorded change—possibly an increased protection of the shed against the entry of sunshine, affecting the 6-inch thermometer—took place; for the diurnal range, which had diminished gradually from 4°·6 in 1847 to 3°·0 in 1848, and 1°·8 in 1849, remained nearly constant thereafter, and there is a large fall of 1°·3 in the annual mean temperature. Simultaneously there is a fall in the diurnal range of the thermometer on the ground, from 11°·5 in 1847 and 10°·6 in 1848, to 9°·0 in 1849, again implying some such change of exposure as has been surmised to have taken place. The movements of the 20-inch and 5-foot thermometers are from first to last almost exactly parallel. Whilst, however, noting in all the curves a sufficient correspondence of movement to be used as evidence that the changes represented are, after allowance for differences of exposure and changes of instrument, mainly true temperature phenomena—the observations in the different positions deriving mutual support each from the other—one cannot but be struck by the fact that the principal inflexions of the curves of air temperature and ground surface temperature, viz., those which have a maximum in 1855, are not the principal inflexions of the 20-inch and 5-foot curves, but that these latter are depressions which give a minimum of temperature in 1858; and we further observe that the 6-inch curve possesses, but with less development, both the features alluded to, the thermometer thus partaking of the movements both of the two thermometers above and of the two below it. We may remark that these phenomena, being inexplicable as due to a flow of heat downward from the local ground surface, require the assumption of a variable flow laterally, or from below. The 12-foot thermometer, showing a small continuous decrease of annual mean temperature, was used for too short a period to afford ground for remark, apart from similar records for other stations. Except in this last case, the general means of all the soil thermometers show a gradual increase of temperature, with increase of depth, but it is impossible to say, at present, how much of this is due to instrumental errors.

96. *Annual variation.*—In Table 45 are shown for each month the excesses of the monthly mean readings of thermometers in the positions specified, above the respective annual mean readings.

TABLE 45.

Thermometer.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Years' Observations made use of.
4½ feet above ground -	−5·6	−4·8	−1·3	+2·2	+5·0	+4·1	+1·2	+0·4	+0·5	+1·3	−0·6	−2·8	1866 to 1872 (hourly).
Laid on the ground. -	−6·1	−4·3	−0·1	+3·2	+5·7	+3·2	+1·3	+0·5	+0·2	+1·5	−0·7	−4·2	1847 to 1859 (do.)
One inch deep - -	−5·8	−4·6	−1·5	+2·2	+5·0	+4·0	+1·7	+0·6	+0·7	+1·3	−0·9	−3·0	1860 to 1872 (do.)
Six inches deep - -	−5·6	−4·2	−0·7	+2·3	+4·8	+3·6	+1·4	+0·5	0·0	+1·2	−0·2	−3·5	1849 to 1859 (do.)
Nine inches deep - -	−4·8	−4·4	−1·9	+1·4	+3·9	+3·9	+2·0	+0·8	+0·6	+1·1	−0·6	−2·4	1860 to 1872 (do.)
Twenty inches deep -	−3·5	−3·8	−2·1	+0·5	+2·7	+3·5	+2·1	+1·0	+0·4	+0·8	0·0	−1·6	1851 to September 1859 (hourly). October 1859 to 1872 (at 1 p.m. only).
Five feet deep - -	−1·5	−2·3	−2·0	−0·7	+1·0	+2·2	+2·0	+1·0	+0·3	+0·2	0·0	−0·5	February 1851 to September 1859 (hourly). October 1859 to 1872 (at 1 p.m. only).
Twelve feet deep - -	−0·6	−1·0	−1·0	−0·7	+0·1	+0·8	+0·9	+0·8	+0·4	+0·2	+0·2	0·0	February 1851 to October 1854 (hourly).

97. In figures 244 to 251, which represent the monthly inequalities of this table, we note the almost exact similarity of form of curves 244 to 247, implying similarity in the annual variation of temperature of the air at a height of $4\frac{1}{2}$ feet above the ground, of that of the ground surface, and of that of the soil at depths of one and six inches. The respective ranges between the least and greatest monthly inequality are 10°·6, 11°·8, 10°·8, and 10°·4. But the corresponding range of air temperature for the years 1848 to 1865, when the protection from radiation was less effectual than after the provision of the thermometer cage, is 11°·6, which is all but identical with that of the thermometer on the ground. The 9-inch curve still closely resembles those already mentioned, but its range (8°·7) is less, and there is an evident retardation of the maximum and minimum phases; and in regard to both these latter characteristics, the 12-foot, 5-foot, 20-inch, 9-inch, and 6-inch curves follow each other in order, the respective ranges being 1°·9, 4°·5, 7°·3, 8°·7, and 10°·4; and the maximum and minimum occurring, in the 12-foot curve, in July and about 1st March respectively. Allowing for these differences of range and position, similarity of form is maintained in the curves of annual variation of temperature at all positions from three to five feet above the ground down to 12 feet below its surface. The influence of the monsoon is apparent in a bold depression of the 20-inch curve, and of the curves of all the higher thermometers; and it is traceable in a downward inflexion of the 5-foot and 12-foot curves, as well as by the maximum following the minimum much within half a year.

98. Following the procedure of Professor J. D. Everett, in dealing with similar observations taken at the Greenwich Observatory, we have calculated, in the manner described in pages (cxcv) to (cc) of the "Greenwich Observations for 1860," the values of the thermal coefficient of the soil at Bombay, from observations at the depths nine inches, twenty inches, five feet, and twelve feet, taken in pairs.

The first step is to find for each depth the coefficients P_1, P_2, and the angles E_1, E_2, (in circular measure) of the expression—

$$\Delta T = P_1 \sin (t + E_1) + P_2 \sin (2t + E_2),$$

in which t is the time, reckoned by degrees at the rate of 360° to the year, and ΔT is the corresponding inequality of temperature, reckoned above or below the mean temperature of the year. Applying Bessel's process to the monthly excesses in Table 45 we obtain—

For nine inches depth	$P_1 = 3{\cdot}41$; $E_1 = 277°\ 15'$:	$P_2 = 1{\cdot}86$; $E_2 = 221°\ 4'$:
For twenty inches depth	$P_1 = 2{\cdot}80$; $E_1 = 270°\ 0'$:	$P_2 = 1{\cdot}45$; $E_2 = 204°\ 58'$:
For five feet depth	$P_1 = 1{\cdot}77$; $E_1 = 257°\ 19'$:	$P_2 = 0{\cdot}86$; $E_2 = 162°\ 36'$:
For twelve feet depth	$P_1 = 0{\cdot}89$; $E_1 = 239°\ 17'$:	$P_2 = 0{\cdot}35$; $E_2 = 138°\ 35'$:

The quantity called the thermal coefficient is $\sqrt{\frac{\pi c}{k}}$, in which k is the conductivity and c the specific heat of the soil, both referred to the unit of volume, and π is the ratio of the circumference of a circle to its diameter. The coefficient is theoretically equal to the difference between the Napierian logarithms of any two values of P_1 divided by the corresponding difference of depth: it is also equal to the difference between any two values of E_1 divided by the corresponding difference of depth; and similar equalities hold good, when we substitute "coefficient multiplied by $\sqrt{2}$" for "coefficient," and

"P_2 and E_2" for "P_1 and E_1" respectively. The values of $\log_\epsilon P_1$ and $\log_\epsilon P_2$, and of E_1 and E_2 (in circular measure) are as follows:—

TABLE 46.

Depth of Thermometer.	$\text{Log}_\epsilon P_1$.	$\text{Log}_\epsilon P_2$.	In Circular Measure.	
			E_1.	E_2.
Nine inches	1·22671	0·62057	4·8389	3·8584
Twenty inches	1·02963	0·37157	4·7124	3·5774
Five feet	0·56929	−0·14849	4·4911	2·8379
Twelve feet	−0·11766	−1·04697	4·1762	2·4187

And for the several combinations of depths—in pairs—we obtain values of the coefficients $\sqrt{\frac{\pi c}{k}}$ as given below.

TABLE 47.

	From P_1.	From E_1.	From P_2.	From E_2.
Nine inches and twenty inches	0·2149	0·1379	0·1920	0·2166
Nine inches and five feet	0·1547	0·0818	0·1280	0·1698
Nine inches and twelve feet	0·1195	0·0589	0·1048	0·0905
Twenty inches and five feet	0·1382	0·0665	0·1104	0·1570
Twenty inches and twelve feet	0·1111	0·0519	0·0971	0·0793
Five feet and twelve feet	0·0981	0·0450	0·0908	0·0423
Means	0·1394	0·0737	0·1205	0·1259
	0·1065		0·1232	

99. The general mean result is 0·1149, and it represents, besides the theoretical quantity $\sqrt{\frac{\pi c}{k}}$, the proportion of itself by which the range of temperature at any depth diminishes per English foot of increase of depth. As one French foot contains 1·0658 English foot, the rate per French foot will be 0·1225. This value does not differ extravagantly from those found by Professor Everett for Edinburgh and Greenwich: these being for Edinburgh—Calton Hill, 0·1156; Experimental Garden, 0·1098; Craigleith Quarry, 0·0674; and for Greenwich, 0·092. Having regard to the large discrepancies in our individual values in Table 47, it would be useless to attempt to apportion due weights to the four sets of mean values. A sufficient explanation of the discrepancies is probably to be found in the fact, which the theory disregards, that at Bombay, for a large part of the year, the permeation of the soil by rain-water tends to equalize the temperature at different depths, apart from similar tendencies by simple conduction. The brass tubes which surround the buried parts of the stems of the thermometers have again the same tendency, by reason of their high conducting power at all times; and some slight

irregularity may be produced by the neglect to allow for the different temperatures of the exposed and unexposed parts of the stems of the thermometers; but as such allowance would affect none of the mean monthly inequalities that we have made use of, to the extent of a tenth of a degree, it could reduce in a very trifling degree the discrepancies in question.

100. It was considered possible thst more accordant results might be obtained by finding the values of the coefficients P_1, P_2, and of the angles E_1, E_2, from the six monthly mean temperatures for the dry season months, November to April, during which season it might be supposed that the conductivity of the soil was less disturbed than in the wet season. Applying the method of least squares, the following values were obtained.

TABLE 48.

Depth of Thermometer.	P_1.	$\text{Log}_\epsilon P_1$.	P_2.	$\text{Log}_\epsilon P_2$.	In Circular Measure.	
					E_1.	E_2.
Nine inches - - -	1·41	0·34643	2·74	1·00686	4·5969	1·8776
Twenty inches - -	1·71	0·53533	1·73	0·54581	3·7577	1·7057
Five feet - - -	1·27	0·24138	0·88	−0·13125	3·4423	0·9646
Twelve feet - - -	0·35	−1·05844	0·40	−0·92383	1·7535	1·4343

And from these numbers were derived the values of the thermal coefficient shown in Table 49.

TABLE 49.

	From P_1.	From E_1.	From P_2.	From E_2.
Nine inches and twenty inches -	−·2060	·9152	·3555	·1326
Nine inches and five feet - -	·0247	·2717	·1893	·1519
Nine inches and twelve feet - -	·1249	·2527	·1213	·0279
Twenty inches and five feet - -	·0883	·0947	·1437	·1574
Twenty inches and twelve feet -	·1543	·1940	·1006	·0186
Five feet and twelve feet - -	·1857	·2413	·0800	−·0474
Means - - -	·0620	·3283	·1651	·0735
	0·1951		0·1193	

101. The mean result (0·1572) per English foot, or 0·1675 per French foot, is less accordant with those of Greenwich and Edinburgh than the former one; and the several individual values of the coefficients are also much less in agreement with each other than before. The unexpected results just obtained, show how cautiously the method of the harmonic analysis should be applied for the determination of the law of a periodical variation by means of observations extending over a part only of the period. Derived from 12 monthly means, the values of P_1 are greater for all the four depths than those of P_2; but

derived from six monthly means P_2 becomes the greater amplitude for all the depths except five feet, and for the 9-inch thermometer is nearly twice as great as P_1. Notwithstanding this, the calculated variation of the 9-inch thermometer agrees closely with observation for the six mean monthly temperatures for November to April, but deviates widely in the remaining half year; and the deviation is not in the direction of high summer temperatures, complementary to the low winter temperatures of December to February, but greatly in exaggeration of the depressions caused by the rains of the monsoon: indeed the term which has a year for its period has maximum and minimum values, not in summer and winter, but in May and November. To exhibit these deviations a dotted curve has been constructed, on the same form with the annual variation (fig. 248) of the 9-inch thermometer, from the following calculated monthly values beginning with January and ending with December, viz., 76·3, 76·3, 79·1, 82·3, 83·1, 81·0, 77·9, 76·7, 78·0, 80·0, 80·3, and 78·4.

102. *Diurnal variation.*—In Table 50 are shown the excesses of the mean temperatures at the several hours of the day, above the mean temperature of the 24 hours, of thermometers in the several positions specified.

TABLE 50.

Thermometer.	In Air.			On the Ground.	In the Ground.		
Position.	Three feet.	Five feet.	4½ feet.		One inch.	Six inches.	Nine inches.
Period.	1848 to 1851.	1853 to 1865.	1866 to 1872.	1849 to 1859.	1860 to 1872.	1849 to 1859.	1860 to 1872.
Hours.							
0	−2·9	−2·7	−2·2	−2·3	−1·4	−0·2	0·0
1	−3·1	−3·0	−2·5	−2·6	−1·7	−0·3	0·0
2	−3·4	−3·4	−2·8	−2·9	−2·0	−0·4	−0·1
3	−3·7	−3·6	−3·1	−3·2	−2·2	−0·6	−0·2
4	−3·9	−3·9	−3·4	−3·5	−2·5	−0·7	−0·3
5	−4·3	−4·2	−3·6	−3·8	−2·7	−0·8	−0·3
6	−4·4	−4·3	−3·8	−3·8	−2·9	−0·9	−0·4
7	−2·7	−3·2	−3·0	−2·7	−2·4	−1·0	−0·5
8	+0·1	−1·2	−1·4	−0·8	−1·4	−0·8	−0·5
9	+2·4	+0·6	0·0	+0·9	−0·4	−0·6	−0·4
10	+3·9	+2·2	+1·4	+2·3	+0·6	−0·3	−0·3
11	+4·9	+3·5	+2·7	+3·3	+1·5	0·0	−0·2
12	+5·4	+4·7	+3·8	+4·0	+2·4	+0·2	−0·1
13	+5·3	+5·4	+4·7	+4·5	+3·0	+0·5	0·0
14	+4·8	+5·7	+5·0	+4·6	+3·4	+0·6	+0·2
15	+3·9	+5·5	+4·9	+4·4	+3·4	+0·8	+0·3
16	+3·2	+4·7	+4·2	+3·7	+3·1	+0·8	+0·3
17	+1·8	+2·9	+2·7	+2·4	+2·2	+0·8	+0·4
18	+0·3	+0·8	+1·0	+0·8	+1·2	+0·7	+0·4
19	−0·3	−0·2	+0·1	0·0	+0·5	+·05	+0·3
20	−0·8	−0·8	−0·4	−0·6	0·0	+0·4	+0·3
21	−1·4	−1·4	−0·9	−1·1	−0·4	+0·3	+0·2
22	−2·1	−2·0	−1·5	−1·6	−0·8	+0·1	+0·1
23	−2·5	−2·4	−1·9	−2·0	−1·2	0·0	+0·1

103. The range of the mean diurnal variation of the temperature of the thermometer 20 inches below the ground surface, derived from the observations of the years 1851 to 1855, or from 1849 to 1855, is less than 0°·1; although, as 78° of the column of mercury are exposed above the ground, the diurnal changes of air temperature alone would cause an apparent range approaching 0°·1. For the years 1849 and 1850, when the thermometer was in the old shed, the range was between 0°·1 and 0°·2. For the first year (1851)—the means being taken only to tenths of a degree—the 12-foot thermometer showed a diurnal range of 0°·1, which would nearly all be due to the expansion of the exposed part of the column of mercury; but for some reason the difference 0°·1, between night and day, disappeared in the two following years of hourly observations, both at 12 feet and five feet depth.

104. The numbers in Table 50 have been curved in figs. 252 to 257. The black curve of figs. 252 to 254 represents the diurnal variation of air temperature for the period 1866 to 1872, and is repeated, for the sake of ready and close comparison, with the corresponding red curves, which refer respectively to the air temperature for the periods 1848 to 1851 and 1853 to 1865, and to the ground surface temperature; whilst figs. 255 to 257 refer to the ground thermometers at depths of one, six, and nine inches.

The relations represented by figs. 252 and 253 have already been remarked upon in paragraph 57, where, and in what precedes, the differences are attributed mainly to difference of exposure. It would seem from the small excess of the ordinates of the ground surface curve (in red), from 7 hours to 11 hours, above those of the air thermometer (1866 to 1872) that the same difference of exposure has affected the temperature of the surface soil in the old thermometer shed, for these and the two following are the hours at which the inequalities of the period 1848 to 1851 so much exceed those of the period 1866 to 1872; and the two years 1849 and 1850, when the ground surface thermometer was in the old shed, may well be supposed to contribute to the diurnal variation found for the period 1849 to 1859 the small excesses in question. The smaller range of the ground surface thermometer, as compared with the air thermometer, arises from the fact that the surface soil in an enclosure protected from solar radiation must owe its alternations of temperature mainly to heat given to it and received from it by the air which flows immediately above it: hence the air is first to change, and it never succeeds in completely heating or cooling the soil to its own extreme temperatures. The diurnal range of the air temperature at the height of 4½ feet, *i.e.* from 1866 to 1872, is 8°·8; that of the period 1853 to 1865, which, so far as the record tells, refers to heights of five and four feet, is 10°·0; and that of the period 1848 to to 1851, at a height of three feet, is 9°·8. We have shown in paragraphs 55 to 57 that the ranges of the two first periods are high, probably by reason of radiation from the roofs of the sheds; and we have in paragraph 56 given experimental proof that exposure to the roof does produce an increased range. The data we possess are, therefore, incompetent to answer the question, How does the range vary with height of the thermometer above the ground?

105. The diurnal variation curves of the 1-inch, 6-inch, and 9-inch thermometers are all similar in form to the air thermometer curve (1866 to 1872), but with rapidly diminishing range as the depth increases, and with retardation of corresponding phases. The ranges are—air, 8°·8; one inch deep, 6°·3; six inches deep, 1°·8; and nine inches deep, 0°·9. On account of the minuteness of the two latter ranges, and because the nominal depth, of

one inch, of the higher ground thermometer can only be regarded as roughly approximate, these variations are unsuited for the determination of the thermal coefficient of the soil; which, moreover, would have little value as applying only to the thin stratum of soil between nine inches deep and the ground surface, a stratum which, of all others, is most subject to variation of condition, and to thermal influences not considered in the theory to which the coefficients refer. Of such influences may be mentioned the permeation of the soil by rain-water, carrying in some degree its own temperature with it, and of such variation the greater or less degree of dryness of the stratum.

Rain Gauges and Rainfall.

106. Two rain gauges, one by Newman, near the ground, and one called Osler's, at some elevation, have been in use for the whole period from 1847 to 1872. The Newman's gauge in use in 1865, and onward to the present time, is of copper, and exposes for the collection of rain-drops a circular surface, of nearly 12 inches in diameter, forming the top of a funnel that carries the rain into a cylindrical vessel below, having a diameter of 5·732 inch. A float of slightly less diameter, so as to rise and fall freely, rests upon the water in this vessel, and having a wholly convex external surface, it allows the rain, as it falls, to flow off and raise the level of the water, and with it the float; to the middle of the float is fixed a wooden rod graduated with divisions, each of which represents approximately ·05 inch of rain; and the readings of this scale, which are easily estimated to fifths of a division, are made where it is cut by the upper edge of a light brass rod, placed horizontally across the mouth of the funnel, but half an inch below the edge of the exposed circular surface; the scale passes through a hole in the middle of the horizontal rod, and is thus kept always in a vertical position. The range of the scale is from 0 to 4·00 inches, and it was customary, before the 13th June 1866, to empty the gauge, by means of a brass cock at the bottom, at every hourly observation, or rather, to let out enough water to bring the scale down to the zero: this was, however, a somewhat doubtful operation, since the float rested at the bottom of the vessel when the reading was nothing, whilst a fall of five hundredths of an inch of rain was necessary to sensibly raise it, and if too much water was let out, there was no change in the position of the scale to indicate the fact. But since the 13th June 1866 the readings of the scale have been entered in the meteorological register, and the differences taken for every interval of an hour; and the rain has accumulated in the vessel till 11 p.m. on every Saturday, or till, from heavy rainfall, the reading had risen generally to somewhere above 2·00 inches, when the water was let out of the vessel till the scale read, *not nothing*, but 0·05 inch, at which point, if too much water was let out, the operator became aware of it, and added a quantity to restore the proper reading. This reading was also maintained during intervals of dry weather—when, from evaporation, the scale would otherwise have fallen lower—by pouring water into the gauge.

Until the 6th July 1867 the rain gauge was read on Saturdays at 11 p.m., and next, unless there was a considerable fall on the Sunday, at 12 p.m. on Sunday, but to render the records complete for every civil day in the year the readings were taken from that date at 12 p.m. on Saturday also.* In 1865 Newman's gauge stood, on three feet attached to it, on a

* Up to the year 1865, in distributing the rainfall in Newman's gauge amongst the 25 hours between 11 p.m. on Saturday and 12 p.m. on Sunday, the contemporaneous registers of Osler's gauge had to be consulted.

large rectangular block of stone near the southern wall of the Magnetical Observatory, with its circular mouth raised 4½ feet above the ground. The roof of the observatory having an elevation of about 32° above the mouth of the gauge in that position, it was considered advisable to remove the gauge to a more open spot, where no obstructions would lie within a considerable distance of it, and this was accordingly done before the commencement of the rains of 1866, some trees that lay in the immediate neighbourhood having been cut down to prepare the new place. On the 2nd May 1866 the mean of several measures of the diameter of the circular surface exposed by Newman's gauge was found to be 12·008 inches, and there is no mention in the observatory records of its having been altered at any time previously. On the 25th June and 5th July 1866, however, and again on the 14th May 1867, the gauge was found to have been knocked down off its support, and the exposed surface was altered thereby on the two latter occasions, giving mean diameters of 12·026 inches and 12·035 inches respectively. Immediately after the latter date the precaution was taken to have the feet of the gauge embedded with lead in holes cut in its stone support. At the close of the year 1868, the gauge, with the stone slab upon which it stands, had to be removed out of the way of the new magnetograph room, and it was placed near the middle of an open space of ground lying between the entrance gate, the small Magnetical Observatory, and the small dome. A tree which would have overlooked the gauge in this position had to be cut down; and an enclosure of light bamboo railings on wooden posts, of the same height as the gauge, was made to prevent the possibility, in so exposed a position, of an unobserved stranger meddling with the instrument. In effecting this removal the measuring scale was accidentally broken, and a new one had to be made, the divisions of which were made of a different length from those of the old scale, with the object of avoiding the necessity of thereafter applying any correction to reduce the registered fall of rain to true inches. After this time the reading to which the scale was set, on discharging the gauge, was 0·10 instead of 0·05 as before. This change was rendered necessary because the zero of the scale of the new wooden rod was slightly higher than on the old one.

Again on the 8th June 1870 the erection of the new thermograph room somewhat near to the rain gauge rendered it advisable to remove the latter further away; and it was accordingly removed, with its enclosure, about 28 feet to the south-westward of its former position. There was only one day of heavy rain—the previous day—before the removal, and on that day the wind was not at all from the direction of the thermograph room; consequently the records are probably not at all affected by the erection of the new building. In the present position the altitude of the highest neighbouring object, as seen from the gauge, is about 30°; and before the last removal it was a little less. Experiments described on page xxxi of the "Introduction to the Bombay Observations for 1864" gave 0·977 as the factor for converting the rainfall as registered by Newman's gauge into absolute measure in inches. The experiments were made in May 1866, when the mean diameter of the surface exposed was 12·008 inches. Taking account of the changes in the extent of this surface described above, the factors adopted for the different periods are—

From 1st January 1865 to 5th July 1866 the factor = 0·977.
„ 5th July 1866 to 14th May 1867 do. = 0·974.
„ 14th May 1867 to 31st December 1868 do. = 0·973.

These factors have been applied. The new wooden scale was inadvertently made to suit the surface exposed during the period from 5th July 1866 to 14th May 1867, and there is consequently a slight error of *one thousandth* of the whole rainfall in the records for the years 1869 to 1874: this it has not been thought needful to correct.

The height above the mean sea level of the mouth of Newman's gauge is about 35 feet, and in the four positions which the gauge has successively occupied since 1865 the height has probably not varied so much as a foot. There is no mention in the records of any change of instrument, but the gauge described as in use in the year 1847, whilst similar in kind, is of different capacity and dimensions from the one at present in use—the former being constructed to contain three inches depth of rain over a circular surface of one foot diameter, and the latter four inches depth. From 1847 to 1852 the height of the gauge above the ground was two feet nine inches, and its distance from the north-east corner of the Magnetic Observatory 35 feet. In 1865 the height was $4\frac{1}{2}$ feet, and the distance $16\frac{1}{2}$ feet; but here again the records are silent as to the time at which the changes of elevation and position were made. Between 1847 and 1852 the height above the mean sea level is said to have been about 35 feet.

Notwithstanding the small differences described, both of height and position, the observations with Newman's gauge will be treated as one continuous and comparable series of measurements; and for the years 1843, 1845, and 1846 the printed records of rainfall, already referred to, will be made use of, as will also the manuscript abstracts for 1844.

107. From before 1847 till 1865 Osler's rain gauge was placed on the roof of the Astronomical Observatory, with its exposed surface for the collection of rain at a height of 26 feet above the ground, and 68 feet above the mean sea level, and the recording apparatus in the room below. The collecting vessel is rectangular in shape, but in May 1866 it was found on examination to be somewhat distorted, and exposed a surface of 197·87 square inches: it was supported on a pyramidal skeleton framework of teak-wood: the lower part of it is funnel shaped, running into a brass pipe which discharges, at its lower end, into a graduated glass receiving vessel suspended by springs from the framework of the recording apparatus. As the water accumulates in the vessel the springs are distended, and the vessel descends till it is nearly filled, when a siphon arrangement within it comes into action, and quickly empties the vessel, and brings it back to its zero of depression. The glass vessel is connected by a thread which passes over a pulley, with a radius bar that carries a pencil in such a way that the pencil approaches the vessel as the vessel fills, and marks its progress on a paper underneath it, which has lines printed on it indicating approximately hundredths of an inch of rain, up to 25 hundredths, this being the quantity which must fall before the siphon empties the vessel. The paper is also marked with hour lines, at right angles to the lines which form the scale, and it is fastened to a flat board, which, being suitably connected with a clock, is carried along uniformly over 24 hour-spaces in one day. By this arrangement the trace of the pencil on the paper informs us what quantity of water there is in the graduated vessel at any moment, and how many times it has been filled and emptied during the day. From 1st to 17th August 1865 the instrument was under repair. In the year 1858 a tower was raised on the east side of this instrument for the time signal ball, forming an objectionable obstruction to the free course of the wind, or causing

a deviation of the wind in the neighbourhood of the gauge. The vertical and horizontal angles subtended by the tower at the gauge were respectively 40° and 42°. On this account the instrument was removed, before the commencement of the rains of the year 1866, to the electrometer tower, where the rectangular funnel was supported on a frame with four teak-wood posts, projecting from the roof of the tower, and raising the exposed surface above the highest point of the roof; and the recording apparatus was placed in the room immediately below. The height of the gauge in this position above the ground is 46 feet, and above the mean sea level 78 feet. In the course of the monsoon of 1866 it became very evident that the recording apparatus was untrustworthy, for the pencil traces often failed, and, owing to friction of the measuring vessel and irregularity in the action of the springs, the indications were far removed from correspondence with the quantities of rain contained in the vessel in the process of filling; so much so, that after emptying, nearly 0·1 inch of rain had to fall before the recording pencil began to move. At the commencement of the following monsoon (1867) its use was therefore discontinued, and the rain was carried by a copper pipe to the basement of the tower, and there discharged into a spare rain gauge of the same construction, but with a different scale, as the one by Newman described above. From three experiments it was found that the same quantity of water which would raise the scale of the spare gauge 1·00 division would raise that of Newman's gauge 1·033 divisions; but this quantity corresponds to $1{\cdot}033 \times 0{\cdot}973$ inches of rain falling on a surface of $(12{\cdot}035) \times 0{\cdot}7854$ square inches; consequently, as the surface exposed by Osler's gauge is 197·87 square inches, the depth of rain which is indicated by a change of 1·00 division of the scale of its spare receiving gauge will be—

$$\frac{(12{\cdot}035)^2 \times 0{\cdot}7854}{197{\cdot}87} \times 1{\cdot}033 \times 0{\cdot}973 = 0{\cdot}5779 \text{ inch.}$$

With this coefficient a table was constructed for converting the hourly differences of the readings of the spare gauge into true inches, and the conversion was made for the previous hour, by the observer, at the time of entering in the register each hourly reading. This practice continued for three years, when a new scale was made, having divisions in the proportion of 1 to ·5779 of the divisions of the old scale, and from 1871 (inclusive) the readings have thus been made directly in true inches. This instrument has been regularly observed since the 7th June 1867 (and since the 6th July 1867 also at 12 p.m. on Saturdays); and on discharging, it has been always set with the scale reading 0·05.

To find how much water was absorbed in wetting the receiving funnel and conducting pipe the spare gauge was filled, on the 11th June 1867, till the scale read 2·00; the water was then drawn off, and all poured into the funnel on the roof of the tower; the scale then read 1·975; consequently ·025 scale divisions or about ·015 inch was lost.

Five minutes later the experiment was repeated with a loss of less than ·006 inch. All rain records will be affected, but especially in hot climates, by evaporation from the wet surface of the receiving funnel: the one just described will show a slightly greater deficiency, because the rain has to wet the conducting pipe as well as the funnel.

In 1847, and in many later years, the exposed surface is said to have been 200 inches, and the registrations of the instrument from that year till 1865 were adopted for record without any correction; but in 1866 it was found, as the result of experiments described in the "Introduction to the Bombay Magnetical and Meteorological Observations, 1864,"

page xxxii, that to obtain the rainfall in true inches the registrations should be multiplied by 0·983: this correction was applied for the year 1866 only, but owing to irregularity of action of the instrument, that year's records will be made no use of.

TABLE 51.

108. TOTAL FALL of RAIN as measured by NEWMAN'S GAUGE in each Month of the Years 1843 to 1874, and NUMBER of RAINY DAYS in each Year.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual Total.	No. of Rainy Days
1843					·15	7·61	20·62	17·70	8·39	·77			55·24	104
1844	·06	·33				18·58	29·28	5·91	8·05	·40		·10	62·71	91
1845						17·88	18·07	9·54	8·63				54·12	86
1846						26·41	33·19	6·65	6·65	1·03			73·93	104
1847	·09	·02		·31	1·40	37·56	16·45	8·68	5·68	·28	5·53		76·00	120
1848				·59	5·67	39·98	13·90	7·37	2·32	5·84	·19		75·86	96
1849	·34					23·41	50·99	12·66	26·13	·75	·61		114·89	100
1850						14·80	20·15	5·39	4·77	4·89	·25		50·25	103
1851					·52	24·50	47·02	20·03	3·89	·04	·07		96·07	89
1852			·01		·30	21·76	22·17	11·16	12·67	·19		1·01	69·27	100
1853		·05	·02			33·70	13·05	5·95	9·83				62·60	84
1854						16·34	38·95	3·90	13·61	7·49	1·85		82·14	114
1855						20·18	11·83	3·82	5·29	·06			41·18	91
1856					2·09	24·66	24·48	6·73	7·78	·06		·12	65·92	109
1857					·57	9·26	8·74	15·71	14·21	2·78			51·27	108
1858				·15	1·57	14·44	20·12	7·48	15·47	3·22			62·45	105
1859						26·87	28·70	14·59	5·94	1·06			77·16	91
1860					·03	21·97	22·39	7·11	8·15	2·50			62·15	93
1361					·69	15·43	25·34	30·35	3·24	1·86			76·91	99
1862					·01	22·31	15·10	12·65	21·69	1·42	·45		73·63	107
1863	·41			·11	·07	33·41	30·78	10·60	9·98	2·32			77·68	109
1864					·01	15·42	13·36	10·72	5·59		·47		45·57	95
1865	·38					10·61	18·28	36·42	4·86	6·16	1·14		77·85	104
1866		·11				13·47	40·34	20·34	3·44	·74			78·44	98
1867						8·70	29·39	12·21	6·80	5·07	·13		62·30	110
1868			·01			13·52	20·43	20·29	7·71	·14	·02		62·12	107
1869					·03	26·22	23·89	15·24	22·56	3·55	·05	·12	91·66	102
1870			·03	·02		21·73	26·43	6·27	7·08	4·65			66·21	109
1871	2·22				1·25	8·91	9·96	8·95	6·01	·25	2·97	·06	40·58	107
1872					·06	24·43	24·84	9·49	16·59	1·07			76·48	98
1873		·05			·51	20·36	16·98	23·96	7·77	·07			69·70	101
1874					·05	18·68	41·24	11·14	11·05	·02			82·18	103
Mean 1847 to 1874	·12	·01	·00	·04	·53	20·45	24·12	12·83	9·65	2·02	·49	·05	70·30	101·9

No rain fell in the months left blank in the above Table.

A day is classed as rainy if only 0·01 inch of rain falls in the course of it.

The mean annual rainfall for the period 1847 to 1874 is 70·30 inches.

109. *Five-year means and periodicities.*—The average annual fall of rain in five-year periods is as follows:—

1846 to 1850, 78·19; 1851 to 1855, 70·25; 1856 to 1860, 63·79; 1861 to 1865, 70·33; and 1866 to 1870, 72·15; and for the three years 1843 to 1845, and the four years 1871 to 1874, the means are respectively 57·36 and 67·23 inches; the numbers point to the periods 1846 to 1850 and 1866 to 1870 as periods of maximum rainfall. It has been shown by Mr. C. Meldrum, the Director of the Mauritius Observatory, after examination of records at stations widely distributed over the globe, that there is in general some excess of rainfall in the three years near the time when the aggregate of sun-spots is a maximum, as compared with the three years near the time when sun-spots are of least aggregate extent.

The mean annual rainfall at Colába is shown in the following table for the periods chosen by Mr. Meldrum.

TABLE 52.

Periods of Minimum of Sun-spots.	Mean Annual Rainfall.	Periods of Maximum of Sun-spots.	Mean Annual Rainfall.
	Inches.		Inches.
1843 to 1845	57·36	1848 to 1850	80·33
1855 to 1857	52·79	1859 to 1861	72·07
1866 to 1868	67·62	1870 to 1872	61·09
Means - -	59·29		71·16

The rainfall of five of the six periods is in accordance with Mr. Meldrum's supposed periodicity; and in the averages of these periods there is an excess of annual rainfall at the time of maximum of sun-spots above that at the time of minimum of 11·87 inches. This is almost exactly the mean range (11·38 inches) shown by the five-year averages in a period of nearly double the duration of the sun-spot period. But besides such as pass through a cycle of change in long periods of 11 years or more, there must be causes in operation which at times produce much greater differences of rainfall than those just referred to in short periods of a year or two, for in the period of 32 years there are five years of greater fall than 80 inches, and six of less than 60 inches; and one of the latter is preceded and followed immediately by one of the former, giving differences of fall in successive years of 64·64 and 45·82 inches. Another of the latter is immediately preceded by one of the former, giving a difference of 40·96 inches; and a third of the latter follows in the second year after one of the former, giving a two-years' difference of 51·08 inches.

110. *Annual variation.*—To obtain the variation of rainfall with the season of the year, the average fall was found for each day in that year, from the actual daily falls of the years 1847 to 1870. These averages are shown in Table 53, and are curved in black ink in fig. 5.

TABLE 53.

AVERAGE RAINFALL of each Day of the Year for the Period 1847 to 1870.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
1						·40	·93	·57	·40	·12	·08	
2						·40	1·12	·66	·41	·17	·06	·01
3						·22	·68	·59	·30	·10		
4						·21	·46	·30	·36	·19	·09	
5						·25	·53	·29	·32	·12	·10	
6				·01	·01	·18	·48	·38	·25	·30		
7						·73	·28	·21	·24	·21		·03
8						·41	·63	·33	·56	·15		
9						·78	·64	·66	·50	·02		
10						·84	·54	·27	·31	·12	·03	
11						1·01	·83	·35	·43			
12						·90	·90	·47	·47	·01		
13						1·07	·99	·50	·27	·06		
14	·01					1·28	1·14	·71	·33	·08		
15					·01	·53	·94	·45	·19	·02		
16						·56	1·82	·25	·46	·02		
17						·71	1·14	·62	·35	·03		
18						1·19	·71	·57	·32	·02		
19				·01		·77	·89	·51	·58	·03	·01	
20						1·15	·63	·40	·37	·09		
21					·01	1·10	·62	·27	·38	·07		
22	·02					·92	·74	·22	·30	·02	·02	
23						·79	·52	·29	·09	·12		
24					·02	·62	1·19	·37	·11	·01		
25						·44	·90	·45	·21			
26					·08	·68	·48	·27	·21		·01	
27					·14	1·17	·66	·33	·17	·03		
28					·08	·39	·68	·15	·21	·09		
29					·05	·57	·87	·26	·32	·05	·01	
30					·02	·52	·66	·47	·12	·03		
31	·01				·10		·62	·55		·01		

111. In the same manner as was done with the daily means of barometric pressure and temperature, six smoothing operations were performed upon these numbers, and the means then taken of each sixth smoothed mean and of the seven preceding and seven following it, and the numbers thus found are taken as representing the normal rainfall on each day of the year. They are shown in Table 54, and are curved in red ink on the same form with fig. 5.

TABLE 54.

NORMAL RAINFALL of each Day of the Year, derived from the actual Rainfall of the Years 1847 to 1870.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
1						·24	·64	·56	·35	·18	·04	
2						·28	·64	·54	·36	·17	·03	
3						·34	·64	·52	·37	·16	·03	
4						·39	·64	·50	·38	·15	·03	
5						·45	·66	·48	·38	·14	·03	
6						·52	·68	·47	·38	·13	·03	
7						·57	·71	·46	·38	·12	·02	
8						·61	·74	·44	·37	·11	·02	
9						·64	·78	·43	·36	·10	·02	
10						·68	·80	·43	·36	·10	·02	
11						·72	·81	·43	·37	·09	·01	
12						·76	·82	·43	·37	·08	·01	
13						·81	·84	·44	·38	·07	·01	
14						·85	·85	·44	·38	·06		
15						·88	·87	·43	·38	·05		
16						·89	·88	·43	·36	·05		
17						·88	·90	·43	·34	·04		
18					·01	·87	·91	·42	·32	·04		
19					·01	·86	·90	·42	·31	·04		
20					·02	·84	·89	·40	·29	·04		
21					·02	·82	·87	·39	·29	·04		
22					·03	·80	·85	·37	·28	·04		
23					·03	·79	·81	·37	·27	·04		
24					·04	·79	·77	·37	·26	·04		
25					·06	·80	·73	·36	·24	·04		
26					·08	·79	·71	·35	·23	·04		
27					·10	·76	·69	·35	·21	·04		
28					·12	·73	·67	·34	·19	·04		
29					·14	·69	·65	·34	·18	·04		
30					·17	·66	·62	·34	·18	·04		
31					·20		·59	·34		·04		
Totals					1·03	20·71	23·56	13·02	9·52	2·36	·30	

112. On the red curve of fig. 5, representing these numbers, we remark that until the 24th May, and after the 15th October, the normal daily rainfall is less than 0·5 inch: from the first date to the 16th June, when it is at a maximum of 0·89 inch per day, the increase is gradual. There is a second maximum of 0·91 inch per day on the 18th July, preceded by a minimum of 0·64 inch per day on the 2nd July, and between this minimum and the maxima on either side of it the changes are gradual. From 18th July to 10th August, and again from 14th September to 16th October and onward, the normal rainfall gradually diminishes, and during the intervening period, from 10th August to 14th September, it is almost uniform.

113. *Connected phenomena attributable to sun's passage to northward of Bombay.*— We may here draw attention to the occurrence of a minimum of rainfall (·64 inch per

day) on 2nd July, with maxima of 0·89 inch on the 16th June, and 0·91 on the 18th July; to the occurrence of a maximum of barometric pressure on 1st and 2nd July, and of minima on 16th June and 16th July, with a range of nearly ·02 inch; to the occurrence of an interruption, lasting from 20th June to 5th July, to the general fall of temperature, preceded and followed by rapid falls of 13 and 12 days' duration; to a similar interruption of the general increase of the west component of the wind, lasting from 18th June to 13th July; and to the occurrence of an upward inflexion, lasting from 20th June to 10th July, in the curve of annual variation of the north component of the wind, as phenomena which are probably connected with and attributable to the passage of the virtual equatorial belt of the atmosphere—*i.e.*, the belt of highest temperature—to the northward of the parallel of latitude in which Bombay lies. The sun is to northward of the zenith of Bombay at its meridian passage on the 75 days between 15th May and 29th July; but as with temperature variations generally, so here the phenomena follow the sun, their middle terms occurring some time after the 21st June. The cooling influence of rain, which is very observable on individual days of excessive rainfall, also makes its impress on the normal temperature of periods of heavy rainfall: thus the maxima of rainfall noted above occur, the first about the middle of the first rapid fall of temperature remarked upon, and the second near the end of the later rapid fall, and the intervening minimum of rainfall occurs towards the end of the intervening period of constant temperature. In explanation of this, it may be stated that not only does the rain come from an elevated region, of the coolness of which it partakes, but the radiant heat from the sun or clouds, which is usually effective in increasing or maintaining the temperature of the soil, and thence of the air above it, is at times of heavy rainfall consumed in evaporating the surface water.

114. *Commencement of monsoon.*—The commencement and conclusion of the monsoon, or rainy season, are times that will depend upon the characteristic we fix upon as indicating the presence or absence of it. We have chosen the dates 1st May and 26th October as decidedly including the earliest beginning and latest ending of the proper south-west monsoon, and within these limiting dates we find the average dates, in the 32 years from 1843 to 1874, of the first fall in one day of 0·01, 0·10, 0·25, and 0·50 inch to be 31st May, 3rd June, 4th June, and 6th June respectively; and the average dates of the last fall in one day of the same several quantities of rain to be 12th October, 8th October, 6th October, and 2nd October respectively.

115. *Periods of early and late monsoons.*—But if we divide the series of 32 dates of commencement of the monsoon into groups, as shown in the following table, we see that the average dates are alternately early and late.

TABLE 55.

AVERAGE DATES in SUCCESSIVE PERIODS on which the DAILY FALL of RAIN first became 0·01, 0·10, 0·25, and 0·50 inch respectively.

Period.	0·01 inch.	0·10 inch.	0·25 inch.	0·50 inch.	Mean Epoch of period.
1843 to 1849	May 30	May 30	June 1	June 1	1846·4
1850 to 1855	June 5	June 6	June 8	June 11	1852·9
1856 to 1861	May 26	May 30	May 30	May 31	1858·9
1862 to 1870	June 3	June 6	June 7	June 9	1866·4
1871 to 1874	May 30	June 4	June 4	June 8	

There are three periods of an early monsoon of which the first two contain seven and six years respectively, whilst the observations of 1874 add only a fourth year to the last period, thus leaving it, as compared with the two first, incomplete. This may account for the averages of the last period giving less early dates than the two others. Between the mean epochs of the first and second early periods there are 12·5 years, and between the mean epochs of the two periods of late monsoon 13·5 years. To fix the duration of the period here indicated a much longer series of observations is requisite; but without going to other records, we are able to obtain more precise evidence of the reality of the period and by a process free in some degree from the necessarily arbitrary grouping of years adopted above. In the following table we have put down for each year from 1843 to 1874 the aggregate rainfall between the 1st May and 4th June inclusive, and the number of days on which rain fell.

TABLE 56.

Year.	Aggregate Rainfall.	Number of Rainy Days.	Year.	Aggregate Rainfall.	Number of Rainy Days.	Year.	Aggregate Rainfall.	Number of Rainy Days.	Year.	Aggregate Rainfall.	Number of Rainy Days.
	Between 1st May and 4th June.			Between 1st May and 4th June.			Between 1st May and 4th June.			Between 1st May and 4th June.	
	Inches.			Inches.			Inches.			Inches.	
1843	1·36	4	1851	0·52	3	1859	0·04	1	1867	0·00	0
1844	2·35	2	1852	0·41	3	1860	0·12	2	1868	0·17	4
1845	0·26	1	1853	0·00	0	1861	4·74	7	1869	0·55	2
1846	1·29	3	1854	0·00	0	1862	0·00	0	1870	0·00	0
1847	6·70	10	1855	0·00	0	1863	0·07	4	1871	1·25	9
1848	14·50	11	1856	6·31	7	1864	0·08	1	1872	0·06	1
1849	2·70	4	1857	1·02	4	1865	0·00	0	1873	6·75	6
1850	0·00	0	1858	4·74	7	1866	0·25	1	1874	1·98	4

Whenever the aggregates for more than two consecutive years are in defect of 1·00 inch we have grouped the years together, thus forming the periods 1850 to 1855, and 1862 to 1870: the years of the three remaining periods, which do not satisfy the condition laid down, are also grouped together. We thus obtain the same periods as before with the following averages of aggregate rainfall and number of rainy days.

TABLE 57.

Period.	Aggregate Rainfall.	Number of Rainy Days.
	Between 1st May and 4th June inclusive.	
	Inches.	
1843 to 1849	4·17	5·0
1850 to 1855	0·15	1·0
1856 to 1861	2·83	4·7
1862 to 1870	0·12	1·3
1871 to 1874	2·51	5·0

Hence the period is more marked even, in the average quantity and duration of rainfall before the 5th June, than in the average dates of occurrence of certain definite falls in a day.

In the same periods the average dates on which, reckoning as far back as the 1st May, the aggregate rainfall up to date reached 1·00 inch are 2nd June, 10th June, 2nd June, 11th June, and 9th June respectively, still to the same effect.

In the whole period, reckoning back from 26th October, the average date on which an aggregate of 1·00 inch of rain is found, is 1st October. There is no variation of the time of ending of the monsoon corresponding to the variation in the time of its beginning, nor any in the mean annual rainfall for the several periods.

116. *Rainfall at different hours.*—The aggregate rainfall at the different hours of the day has been found for the two periods 1847 to 1865, and 1866 to 1870, separately as well as combined, and each aggregate being divided by the average of the aggregate falls at all the hours, the ratios obtained indicate whether there is any greater tendency for rain to fall at certain hours than at others. The three sets of ratios are shown in the following table.

TABLE 58.

Hours.	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12
1847 to 1865	1·08	1·15	1·02	1·25	1·13	1·10	1·13	1·14	1·19	1·09	1·00	0·90
1866 to 1870	0·98	0·81	0·93	1·15	0·97	0·89	0·97	0·83	1·02	1·13	1·03	1·25
1847 to 1870	1·06	1·09	1·01	1·23	1·10	1·06	1·10	1·08	1·16	1·09	1·01	0·97

TABLE 58—*continued.*

Hours.	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17	17 to 18	18 to 19	19 to 20	20 to 21	21 to 22	22 to 23	23 to 24
1847 to 1865	0·88	0·83	1·01	0·85	0·76	0·90	0·91	0·95	0·85	1·03	0·90	0·93
1866 to 1870	1·14	1·19	1·24	0·82	0·89	0·89	0·93	1·27	0·86	1·00	0·78	0·98
1847 to 1870	0·93	0·90	1·06	0·84	0·78	0·90	0·91	1·01	0·85	1·03	0·88	0·94

In the combined period the rain which fell during the hours from 0 to 12 was greater by about one-sixth than that which fell in the remaining half day; but in the last period the excess of rain fell in the half day between 8 and 20 hours, and to the extent of about one-eighth. Thus the two periods give the preponderance of rainfall to nearly opposite parts of the day; and the regular flow that characterizes a true variation is missing in the ratios of both periods.

117. *Variability of rainfall.*—In Table 59 are shown the greatest quantities of rain that fell in one hour, in one day, and in one month respectively, in the several years from 1847 to 1874.

TABLE 59.

Year.	In one Hour.				In one Day.			In one Month.		Year.	In one Hour.				In one Day.			In one Month.	
	Quantity.	Time of Fall.			Quantity.	Date.		Quantity.	Month.		Quantity.	Time of Fall.			Quantity.	Date.		Quantity.	Month.
	Inches.	Hour.	Day.	Mth.	Inches.	Day.	Month.	Inches.			Inches.	Hour.	Day.	Mth.	Inches.	Day.	Month.	Inches.	
1847	4·22	3 to 4	12	6	12·54	11	6	37·56	6	1861	2·02	9 to 10	14	7	6·08	18	8	30·35	8
1848	2·20	22 to 23	14	6	8·14	14	6	39·98	6	1862	3·00	17 to 18	9	9	6·16	21	6	22·31	6
1849	1·39	0 to 1	17	7	6·35	25	7	50·99	7	1863	1·84	17 to 18	24	7	8·14	24	7	30·78	7
1850	1·70	12 to 13	13	6	4·61	17	7	20·15	7	1864	1·07	1 to 2	27	8	3·56	26	6	15·42	6
1851	1·90	13 to 14	14	7	6·51	25	8	47·02	7	1865	1·05	14 to 15	14	8	7·86	2	7	36·42	8
1852	1·96	0 to 1	21	6	7·09	22	6	22·17	7	1866	2·62	14 to 15	2	8	7·63	11	7	40·34	7
1853	2·35	3 to 4	9	6	9·89	18	6	33·70	6	1867	1·93	0 to 1	5	7	5·41	16	7	29·39	7
1854	1·42	7 to 8	14	6	5·55	14	6	38·95	7	1868	1·00	12 to 13	16	7	10·23	9	8	20·43	7
1855	1·34	19 to 20	26	6	4·79	20	6	20·18	6	1869	1·11	18 to 19	12	7	15·31	27	6	26·22	6
1856	1·77	9 to 10	9	6	10·28	9	6	24·66	6	1870	1·43	19 to 20	13	10	4·71	18	6	26·43	7
1857	1·12	13 to 14	1	8	5·27	1	8	15·71	8	1871	1·88	21 to 22	31	8	4·64	31	8	9·96	7
1858	1·50	21 to 22	9	7	6·15	11	9	20·12	7	1872	3·07	22 to 23	12	9	9·23	12	9	24·84	7
1859	2·16	21 to 22	16	7	8·20	12	6	28·70	7	1873					6·23	24	8	23·96	8
1860	1·91	2 to 3	16	7	7·31	13	6	22·39	7	1874					4·48	21	7	41·24	7

There was also a heavy fall of 7·20 inches between 10 p.m and midnight of the 12th September 1872.

The greatest fall of rain in one hour during the period of 28 years was 4·22 inches, and fell between 3 and 4 a.m. of the 12th June 1847.

The greatest fall on one day was 15·31 inches, on the 27th June 1869, and the greatest fall in one month (July 1849) was 50·99 inches.

The numbers in Table 59 are curved in figs. 200 to 202.

118. Table 60 shows the maximum rainfall in one day in each month of the year, represented also by fig. 203; the number of rainy days in each month in the period of 28 years (1847 to 1874); and the average number of rainy days per year, occurring in each month,—a day being classed as rainy if only 0·01 inch fell in the course of it.

TABLE 60.

Month.	Maximum Rainfall in one day (1847 to 1874).	Number of Rainy Days in 28 years (1847 to 1874).	Average Number of Rainy Days per Year.	Month.	Maximum Rainfall in one day (1847 to 1874).	Number of Rainy Days in 28 years (1847 to 1874).	Average Number of Rainy Days per Year.
	Inches.				Inches.		
January -	1·87	7	0·2	July - -	8·14	765	27·3
February -	0·11	3	0·1	August -	10·23	723	25·8
March -	0·03	4	0·1	September -	9·23	532	19·0
April -	0·47	8	0·3	October -	2·99	120	4·3
May -	1·78	52	1·9	November -	2·48	32	1·1
June -	15·31	598	21·4	December -	0·83	8	0·3

The average number of rainy days per year is 101·9, and the average number of rainless days 263·4.

119. Table 61 shows the number of days in each fortnight of the year, and for the years 1847 to 1870, when the daily rainfall was 0·00 or lay between 0·01 and 0·49 inch, between 0·50 and 0·99 inch, and so on for every half inch:

TABLE 61.

Daily Rainfall between	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		December.	
	FORTNIGHT.																							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Inches. 15·00 and 15·49												1												
14·50 and 14·99																								
14·00 and 14·49																								
13·50 and 13·99																								
13·00 and 13·49																								
12·50 and 12·99											1													
12·00 and 12·49																								
11·50 and 11·99																								
11·00 and 11·49																								
10·50 and 10·99																								
10·00 and 10·49											1				1									
9·50 and 9·99												1												
9·00 and 9·49																								
8·50 and 8·99																								
8·00 and 8·49											2			1										
7·50 and 7·99													2											
7·00 and 7·49											1	1			1									
6·50 and 6·99															1	1								
6·00 and 6·49												1		1		1	2							
5·50 and 5·99											2	1		1										
5·00 and 5·49												1	2	5	2		1							
4·50 and 4·99											1	3	1	4		1	1							
4·00 and 4·49											4	4	7	3	1			1						
3·50 and 3·99											2	3	6	6			2							
3·00 and 3·49											3	5	6	6	3	2	1	4						
2·50 and 2·99											5	7	8	9	2	4	2	2	3					
2·00 and 2·49											13	14	12	13	2	8	5	5			2			
1·50 and 1·99										2	10	14	14	25	8	6	4	8	4	2				
1·00 and 1·49										1	21	30	32	23	20	11	13	14	6	2	1			
0·50 and 0·99										8	35	50	37	45	39	38	38	27	11	6	4		1	
0·01 and 0·49	1	4	2			4	3	5	3	22	116	166	172	206	223	243	206	120	50	29	8	13	4	2
Total between 0·01 and 15·49	1	4	2			4	3	5	3	33	217	302	299	348	303	315	275	181	74	39	15	13	5	2
Below 0·01	359	380	334	342	360	380	357	355	357	351	143	58	61	36	57	69	85	179	286	345	345	347	355	382
Total Number of Days	360	384	336	342	360	384	360	360	360	384	360	360	360	384	360	384	360	360	360	384	360	360	360	384

120. The numbers in Table 62 are obtained from those in Table 61 by dividing the numbers in each column by the total number at the foot of it, and they represent the probabilities of occurrence of rainfall within the several limits in each fortnight; the numbers in the last line are the ratios of the number of falls between 0·01 and 0·49 to the total number of rainy days.

TABLE 62.

PROBABILITIES of a DAY'S RAINFALL in each FORTNIGHT of the Year being nothing, or lying between the limits 0·01 to 0·49 inch, 0·50 to 0·99 inch, &c., &c.

Daily Rainfall between	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		December.	
	FORTNIGHT.																							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Inches.																								
15·00 and 15·49												·003												
14·50 and 14·99																								
14·00 and 14·49																								
13·50 and 13·99																								
13·00 and 13·49																								
12·50 and 12·99											·003													
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11·00 and 11·49																								
10·50 and 10·99																								
10·00 and 10·49											·003				·003									
9·50 and 9·99												·003												
9·00 and 9·49																								
8·50 and 8·99																								
8·00 and 8·49											·006			·003										
7·50 and 7·99													·006											
7·00 and 7·49											·003	·003			·003									
6·50 and 6·99															·003	·003								
6·00 and 6·49												·003		·003		·003	·006							
5·50 and 5·99											·006	·003		·003										
5·00 and 5·49												·003	·006	·013	·006		·003							
4·50 and 4·99											·003	·008	·003	·010		·003	·003							
4·00 and 4·49											·011	·011	·019	·008	·003			·003						
3·50 and 3·99											·006	·008	·017	·016			·006							
3·00 and 3·49											·008	·013	·017	·016	·008	·005	·003	·011						
2·50 and 2·99											·013	·019	·022	·023	·006	·010	·006	·006	·008					
2·00 and 2·49											·036	·039	·033	·034	·006	·021	·014	·014			·006			
1·50 and 1·99									·005	·028	·039	·039	·065	·022	·015	·011	·022	·011	·005					
1·00 and 1·49									·003	·058	·083	·089	·060	·055	·029	·036	·039	·017	·005	·003				
0·50 and 0·99									·021	·097	·139	·103	·117	·108	·099	·106	·075	·031	·017	·011		·003		
0·01 and 0·49	·003	·010	·006			·010	·006	·014	·008	·057	·322	·461	·478	·536	·619	·633	·572	·333	·139	·076	·022	·036	·011	·005
Below 0·01	·998	·990	·994	1·000	1·000	·990	·994	·986	·992	·914	·397	·161	·169	·194	·158	·180	·236	·407	·794	·898	·958	·964	·986	·995
(0·01 and 0·49) ÷ (0·01 and 15·49)	1·000	1·00	1·000			1·000	1·000	1·000	1·000	·667	·535	·550	·575	·592	·736	·771	·749	·663	·676	·744	·533	1·000	·800	1·000
Fortnightly means	0·01	0·04	0·01	0·00	0·00	0·00	0·02	0·02	0·02	0·52	9·23	11·60	11·11	13·15	6·76	5·99	5·32	4·21	1·68	0·61	0·38	0·06	0·05	0·00

121. The numbers in the last line but two represent the probabilities in the several fortnights respectively of a day being rainless. They tell us that, on the whole, the chances are more than a hundred to one against the occurrence of a rainy day between 1st December and 15th May; that there are, on the average, 1·4 rainy days between 16th and 31st May, 4·7 in the month of October, and 1·2 in November; and that in the remainder

of the year the numbers of rainless days are from 1st to 15th June, 6·0; from 16th June to 15th July, 4·9; from 16th to 31st July, 1·5; in August, 5·2; from 1st to 15th September, 3·5; and from 15th to 30th September, 7·5 days.

The numbers in the last line but one of Table 62 are designed to answer the following question: Given the condition that a particular day is a rainy day, what is the probability that the total fall in the day will be less than half an inch? As none of them are so small as 0·5, the chances are at no part of the year in favour of a fall being so great as half an inch in a day. In the two fortnights of August, the first of September, and the last of October the chances are nearly as three to one against a fall being so great as 0·50 inch: in the last half of May, and from the middle of September to the middle of October, the chances are as two to one against, and throughout June and July, and in the first fortnight of November, the chances against a fall reaching 0·50 inch are rather greater than those in its favour.

In the months from June to November the number of occurrences of heavy rainfall, exceeding 2·00 inches in a day, were 77, 93, 30, 26, 3, and 2 respectively, in the period of 24 years; in the rest of the year no such excessive falls occurred. These numbers give for the probabilities of 2·00 inches or more, in the several months named, ·107; ·125, ·040, ·036, ·004, and ·003 respectively; or, in other words, there is in the average in June one such day in about 10, in July one in eight, in August one in 25, in September one in 28, and in October and November they are of extremely rare occurrence.

On 35 occasions only, in the 24 years, did the rainfall of one day exceed 5·00 inches, and on four only did it exceed 10·00 inches.

The stepped pyramids of fig. 209 have been constructed to represent the probabilities of Table 62.

122. Although the normal daily rainfall is in excess of 0·50 inch for the long period from 6th June to 3rd August, we see from Table 62 that the probable fall of a single day never reaches that quantity: the reason of this is that occasional falls which are greatly in excess of the normal have the weight of the excessive fall in influencing the average, but only the same weight as any other day in determining the probable fall. On this account—the distribution of falls in excess and in defect of the normal being very unequal—the method of probable errors may be applied with less propriety to the rainfall than to other meteorological phenomena. Nevertheless, the numbers yielded in this case, although generally absurd if interpreted in the ordinary manner, are of value, in that they show the great incompleteness with which the average rainfall represents the actual phenomena observed. Derived from the daily abnormals of the years 1847 to 1870 they are as follows:—

TABLE 63.

PROBABLE ERRORS of the NORMAL DAILY RAINFALL in each Fortnight of the Year.

Month	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		Oct.		Nov.		Dec.	
Fortnight	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Probable errors in inches	·01	·02	·00	·00	·00	·00	·02	·01	·01	·12	·93	·97	·80	·83	·66	·50	·52	·41	·25	·12	·13	·02	·03	·00

TABLE 64.

123. TOTAL FALL of RAIN, as measured in OSLER'S GAUGE, placed at a height of 26 feet above the ground, in each Month of the Years 1847 to 1865.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual Total.
1847	·22	·02		·27	1·13	36·52	15·99	8·29	5·21	·29	5·71		73·65
1848				·58	4·27	40·76	14·61	7·07	2·50	5·39	·19		75·37
1849	·30					23·17	48·14	12·31	27·77	·80	·61		113·10
1850						12·62	19·22	4·71	4·83	4·29	·22		45·89
1851					·53	23·34	44·40	19·59	3·69	·04	·07		91·66
1852			·02		·30	21·42	22·19	10·51	12·76	·19		1·07	68·46
1853			·01			33·56	12·59	5·70	10·27				62·13
1854						16·18	38·56	3·50	13·31	7·49	1·78		80·82
1855						19·68	11·38	3·75	5·06	·06			39·93
1856					2·00	23·34	22·06	6·57	7·53	·06		·12	61·68
1857					·60	9·20	8·74	15·91	14·31	2·78			51·54
1858				·20	1·57	14·34	19·97	7·89	16·09	3·33			63·39
1859						26·87	28·70	15·04	5·94	1·06			77·61
1860					·03	20·89	22·56	7·03	8·27	2·40			61·18
1861					·66	14·90	25·32	29·13	2·93	1·70			74·64
1862					·01	21·43	12·74	11·50	19·61	1·42	·36		67·07
1863	·41			·09	·07	21·92	30·31	10·30	10·14	2·06			75·30
1864					·01	15·39	13·64	9·29	5·07		·43		43·83
1865	·35					10·24	17·34	33·12	4·42	6·04	1·22		72·73
Mean, 1847 to 1865	·07	·00	·00	·06	·59	21·36	22·55	11·64	9·46	2·07	·56	·06	68·42

TABLE 65.

TOTAL FALL of RAIN, as measured in OSLER'S GAUGE, placed at a height of 46 feet above the ground, in each Month of the Years 1867 to 1874.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual Total.
1867						8·12	27·92	11·36	6·45	5·03	·07		58·95
1868						11·55	18·02	18·14	7·35	·14	·01		55·21
1869					·02	21·85	20·57	13·89	20·76	3·39	·05	·10	80·63
1870			·02	·02		19·49	23·73	5·48	6·36	4·42			59·52
1871	1·98				1·03	7·79	8·11	7·91	5·35	·18	2·49	·05	34·89
1872					·03	22·16	21·15	7·84	15·32	1·04			67·54
1873		·03			·37	18·37	14·50	21·10	7·08	·04			61·49
1874					·04	16·12	37·08	9·39	10·27	·01			72·91
Mean, 1867 to 1874	·25	·00	·00	·00	·19	15·68	21·38	11·89	9·87	1·78	·33	·02	61·39

124. *Comparison of rainfall at different heights.*—In Table 66 is shown the ratio of the fall in Osler's gauge to the fall in Newman's, for each year from 1847 to 1865, when the former was at a height above the ground of 26 feet; and for each year from 1867 to 1874, when the former was at a height of 46 feet.

TABLE 66.

Year.	Fall in Osler's ÷ Fall in Newman's.	Year.	Fall in Osler's ÷ Fall in Newman's.
1847	·97	1867	·95
1848	·99	1868	·89
1849	·98	1869	·88
1850	·91	1870	·90
1851	·95	1871	·86
1852	·99	1872	·88
1853	·99	1873	·88
1854	·98	1874	·89
1855	·97		
1856	·93		
1857	1·00		
1858	1·01		
1859	1·01		
1860	·98		
1861	·97		
1862	·91		
1863	·97		
1864	·96		
1865	·93		
Mean of nineteen years	·97	Mean of eight years	·89

Thus, in the average, the rainfall at the height of 26 feet was to the rainfall at a height of $4\frac{1}{2}$ feet (about) as ·97 to 1, and the rainfall at a height of 46 feet to that at $4\frac{1}{2}$ feet as ·89 to 1; but if we applied to the whole preceding period the correction which we found in 1856 to be requisite in the case of Osler's gauge, by multiplying the recorded fall by ·983, the ratio for the 19 years would become ·95, and the ratios for the individual years would all become less than unity.

125. But this phenomenon of the accumulation of rain in the course of its fall is worthy of a closer examination. On dividing the observations of the years 1867 to 1873, which the writer has personal knowledge of the trustworthiness of, and which have been corrected for errors of the instruments, into days when the fall in Newman's gauge was ·50 inch and below, and above ·50 inch respectively, and comparing the corresponding days' falls in Osler's gauge, we obtain the following results, grouped in years and months.

TABLE 67.

AGGREGATE RAINFALL in the Years 1867 to 1873.

Year.	Newman's Gauge.		Osler's Gauge.		Fall in Osler's Gauge ÷ Fall in Newman's Gauge.	
	Daily Fall.		Daily Fall.		Daily Fall.	
	·50 inch and below.	Above ·50 inch.	·50 inch and below.	Above ·50 inch.	·50 inch and below.	Above ·50 inch.
1867	11·24	51·06	10·39	48·55	·92	·95
1868	10·85	51·27	9·36	45·85	·86	·89
1869	8·95	82·71	7·61	73·02	·85	·88
1870	10·87	55·34	9·27	50·25	·85	·91
1871	12·05	28·53	9·58	25·31	·80	·89
1872	12·24	64·24	9·66	57·88	·79	·90
1873	10·98	58·72	8·75	52·74	·80	·90
Means 1867 to 1873	11·03	55·98	9·23	50·51	·84	·90

TABLE 68.

Month.	Newman's Gauge.		Osler's Gauge.		Fall in Osler's Gauge ÷ Fall in Newman's Gauge.	
	Daily Fall.		Daily Fall.		Daily Fall.	
	·50 inch and below.	Above ·50 inch.	·50 inch and below.	Above ·50 inch.	·50 inch and below.	Above ·50 inch.
January	·35	1·87	·28	1·70	·80	·91
February	·05	·00	·03	·00		
March	·04	·00	·02	·00		
April	·02	·00	·02	·00		
May	1·08	·77	·77	·68	·71	·88
June	11·98	111·89	10·24	99·08	·85	·89
July	19·98	131·94	16·09	117·91	·81	·89
August	25·26	71·15	20·90	64·82	·83	·91
September	14·75	59·77	12·93	55·74	·88	·93
October	2·89	11·91	2·71	11·53	·94	·97
November	·60	2·57	·48	2·14	·80	·83
December	·18	·00	·15	·00		

The ratios are always less than unity, and those for the lighter falls are invariably smaller than those for the heavier rains. The mean ratio for light rains is ·84, and that for heavy rains ·90; showing that, on the average, light rains accumulate more in the stratum of air intervening between the heights 4½ feet and 46 feet than heavy rains do, and to the extent of nearly seven per cent. of the total of light rains. Very heavy rains of more than

2·00 inches in a day give the ratios 0·91, which is sensibly the same as for rains between ·50 and 2·00 inch. The quantity of what we have called light rains is only about a sixth of the total rainfall, and it is certain that the small ratio given by the light rains is to be attributed in some degree to the evaporation from the leading pipe of the upper gauge; but this can have but very little influence on days of more than 2·00 inches of rainfall, in which, nevertheless, there is a deficiency of about 10 per cent. in the upper gauge as compared with the lower; neither does it seem to be adequate to the production of a further difference of seven per cent. in the aggregate quantity of light rains.

Anemometers, and Direction and Movement of the Wind.

126. Until the end of the year 1865 the anemometer in use at the Colába Observatory was an uncouth machine that gave much trouble and little useful return for it. From roughness of the arrangements for supporting it, and from exposure of the instrument to the weather, the friction was very great, and in view of better materials now existing it is considered undesirable to make any use of either the direction or pressure registrations obtained from the old instrument, beyond the abstraction from them of maximum winds.

For the 18 months from January 1866 to June 1867 the velocity of the wind was obtained from hourly readings on week days, and readings at the beginning and end of Sundays, of a diminutive makeshift anemometer provided with Robinson's rotating cups. The conversion of the indications of this instrument into miles per hour of velocity was effected by means of a factor determined from simultaneous records of this instrument and the one presently to be described; but the converted velocities have been used only for the abstraction of maximum winds.

127. *Description.*—From the beginning of the month of June 1867 was brought into use an anemograph, of the kind designed by Dr. Robinson, with improvements by Mr. Robert Beckley. It was made by Mr. R. W. Munro, and was supplied through the Kew Committee of the British Association, after being tested at the Kew Observatory. In this instrument the arrangements for the registration both of movement and direction of the wind are mounted on one shaft, and the registrations are made on a single sheet of paper, which is changed daily. The essential part of the apparatus for measuring the movement is a vertical spindle, to which cross arms are attached at the top, carrying four hemispherical cups of copper; the cups are attached to their several arms, so that, looking from the central axis, their convex sides are seen turned to the right hand; and the wind, acting with greater effect upon the concave than on the convex sides of the cups, causes the system to rotate in a right-handed direction. It is the number of these rotations, 140 of which are reckoned to a mile of movement of the wind, that tells us how fast the wind has been blowing; and the number is reduced by means of wheelwork 7,000 times before reaching a small cylinder, carrying a brass spiral pencil that traces the movement on the registering paper; this latter is metallic paper, of the kind used for pocket-books, and is wrapped round a brass cylinder, which is kept rotating by clockwork, and as the paper passes under the spiral pencil, which presses slightly upon it, the black movement-trace is received upon it. The wind vane, which consists of a pair of windmill vanes with connecting spindle, having an endless screw in the middle, and gearing into a *fixed* horizontal toothed wheel, is attached to a tube that surrounds the lower part of the vertical movement spindle; to the bottom of the tube

is fixed a toothed wheel, which, in communication with other such wheels, conveys the motion of the vane *unchanged* to a small cylinder with spiral pencil, which traces the changes of direction on the register; and it is so arranged that the movement and direction are traced on parallel strips or bands of the same sheet of paper. The heavy parts of the instrument—the direction vane and appendages, and two long brass tubes which connect the instrument proper with the recording apparatus—are supported on friction balls which run in grooves partially filled with oil, thus reducing the friction to a minimum. The instrument is erected on the old time-ball tower, at a height of 53 feet above the ground, and 95 feet above the mean sea level, over a platform 12 feet in diameter, which is designed to give ready access to the instrument, and to protect it from irregular currents of wind glancing from the convex surface of the dome; and it is supported outside by a fixed cast-iron standard, to which is attached, at the top, the toothed wheel into which the endless screw of the spindle connecting the windmill vanes gears. The centres of each pair of opposite hemispherical cups are four feet apart, and three and a half feet above the platform, and the diameter of the cups is nine inches. The diameter of the vanes is 15 inches, and the breadth of the fans four inches. The register form is printed in red, with lines dividing its length into hour spaces; and its breadth on the movement side, into five spaces, each representing 10 miles of movement of the wind, and numbered from 0 to 50 miles; and on the direction side, into spaces corresponding to 11¼ degrees on each side of the 16 principal directions N., N.N.E., N.E., &c. . . . . N.N.W., which spaces are numbered consecutively 1, 2, 3, &c. . . . . 16.* Seven years of records with this instrument, viz., from June 1867 to May 1874, are available for discussion.

128. *Tabulation of anemograms.*—Numerical tabulations have been made of the movement and direction of the wind during the interval between every two successive hours in the following manner:—the number of miles indicated at the point where the velocity trace cuts a horizontal hour-line being read for two successive hours, the excess of the latter over the former reading (adding 50 if the trace has passed over from left to right of the form) gives the movement for the interval; and the number of the space in which the direction trace lies during the interval is entered as representing the direction. The estimations of movement are made only to the nearest full mile. Should the direction trace not lie all in one space during the whole interval of an hour, then if the change of direction exceed 90° or eight points, the whole observation for that hourly interval is rejected, but if it lie within that limit the direction is estimated—by an inspection of the movement and direction traces together—from whence the aggregate flow of air was the greatest, and this direction is adopted for the full hour. In the first year, of 8,568 hours, during which the instrument was in action, 16 only had to be rejected, because the direction of the wind varied more than eight points within the hour.

129. *Method of reduction.*—Hitherto we have had to deal with phenomena liable only to simple increase and decrease of value, and not subject to any change of quality. Such phenomena being properly and completely evaluated by simple numbers, we may apply to the numbers any arithmetical operations such as averaging, and infer from the results of those operations corresponding properties of the phenomena. But we have

*A more detailed account of the Colába anemograph will be found in the "Bombay Magnetical and Meteorological Observations, 1865 to 1870," Appendix I, page 199.

now come to a phenomenon which requires two numbers to express it, one representing its amount and the other a varying quality; the first referring to the velocity, and the last to the direction of the wind. Here we may no longer apply arithmetical processes directly and indiscriminately to the observed numbers; but, the subject being one of motion, we must treat them according to the principles of the science of motion. These principles tell us that the motions may be equally well expressed by means of two varying numbers referring to two invariable qualities, as by a varying number referring to a varying quality; and they show us how to obtain either form of expression from the other. The invariable qualities chosen in the present case are the directions north and east, the actual wind blowing in each hour being resolved into north and east components, which may be regarded separately as the velocity of the wind in the invariable direction north or south, and the velocity of the wind in the invariable direction east or west. The resolutions are effected by means of the formulæ—

$$\text{North component of velocity of wind} = m \cos (n \times 22^\circ\tfrac{1}{2}),$$
$$\text{East component of velocity of wind} = m \sin (n \times 22^\circ\tfrac{1}{2}),$$

where m is the movement observed, and n the number of the direction space under which the wind of the hourly interval is classed. When the sign of either of these calculated quantities is negative, it implies that the wind blows from the opposite direction, *i.e.*, from south or west. The calculations are readily made by means of tables to the nearest tenth of a mile of velocity per hour. Having now substituted the two equivalent winds for the real one, we may with propriety proceed to combine together numbers of observations by algebraical addition and averaging, treating the north and east components of the wind each by themselves. The averages thus found from the observations of any given period will represent the velocity with which the wind must blow from the northward (from the southward if the sign of the average be negative) continuously for the whole period, in order that the total movement of the wind from that direction may be the same as the total movement from the same direction, produced by the winds which actually blow, and similarly the velocity with which it must blow continuously from the eastward, (westward if the sign of the average be negative).

130. *Annual and monthly means.*—Such averages have been calculated for every month in each of the seven years, with the results shown in Table 69.

TABLE 69.

WIND: the MEAN COMPONENTS of the WINDS which blew in each Month of Seven Years; the direction of the component Winds being North or South and East or West, and their Velocities being expressed in Miles per Hour.

June.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		Means for the Seven Years.	
N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	N or S	E or W	
Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	
4·5 S.	11·6 W.	6·3 S.	15·4 W.	4·1 S.	17·0 W.	2·6 S.	8·3 W.	4·0 N.	0·3 W.	7·7 N.	1·7 E.	6·6 N.	0·8 W.	8·0 N.	0·7 W.	6·9 N.	3·6 W.	7·9 N.	5·8 W.	4·7 N.	7·3 W.	0·2 N.	7·3 W.	2·4 N.	6·6 W.	1868
3·6 S.	12·0 W.	5·0 S.	13·0 W.	3·2 S.	17·1 W.	0·8 S.	7·0 W.	4·4 N.	0·8 W.	5·3 N.	1·1 E.	8·6 N.	0·3 E.	9·3 N.	2·1 W.	8·1 N.	4·2 W.	6·6 N.	6·4 W.	3·1 N.	8·7 W.	1·6 N.	8·0 W.	2·1 N.	6·2 W.	1869
0·8 S.	7·9 W.	3·5 S.	17·5 W.	2·1 S.	9·6 W.	4·6 S.	3·6 W.	5·0 N.	3·7 W.	6·4 N.	2·4 E.	5·7 N.	0·0	8·8 N.	2·6 W.	8·0 N.	2·6 W.	8·4 N.	3·4 W.	4·6 N.	6·6 W.	0·1 S.	6·4 W.	1·7 N.	5·0 W.	1870
0·4 S.	9·7 W.	5·7 S.	17·1 W.	1·9 S.	15·2 W.	0·2 N.	4·0 W.	4·2 N.	1·3 W.	3·5 N.	0·2 W.	5·4 N.	1·3 E.	7·2 N.	0·0	6·2 N.	3·6 W.	4·3 N.	4·0 W.	2·2 N.	5·5 W.	0·4 S.	5·0 W.	1·7 N.	3·3 W.	1871
4·6 S.	11·6 W.	4·5 S.	20·0 W.	3·0 S.	17·3 W.	2·5 N.	6·7 W.	4·6 N.	2·2 W.	2·4 N.	1·9 E.	6·5 N.	0·7 W.	8·8 N.	3·0 W.	8·4 N.	5·1 W.	5·0 N.	5·4 W.	7·3 N.	6·7 W.	1·1 N.	5·7 W.	2·8 N.	7·3 W.	1872
0·3 S.	8·2 W.	5·2 S.	18·1 W.	3·7 S.	15·1 W.	1·8 N.	5·3 W.	4·5 N.	0·8 W.	5·5 N.	2·7 E.	4·5 N.	0·2 E.	8·3 N.	1·1 W.	7·6 N.	0·6 W.	4·3 N.	6·1 W.	5·6 N.	6·5 W.	1·5 N.	6·4 W.	2·2 N.	5·6 W.	1873
0·9 S.	5·4 W.	9·6 S.	19·7 W.	1·8 S.	15·3 W.	0·4 S.	7·7 W.	5·0 N.	0·8 W.	5·6 N.	0·7 E.	7·0 N.	0·4 E.	8·1 N.	1·4 W.	7·2 N.	2·5 W.	7·0 N.	3·5 W.	5·1 N.	6·5 W.	0·6 S.	7·6 W.	1·0 N.	5·8 W.	1874
2·8 S.	10·0 W.	6·4 S.	17·5 W.	3·2 S.	15·2 W.	0·4 S.	7·6 W.	4·5 N.	1·4 W.	5·8 N.	1·4 E.	6·0 N.	0·2 E.	7·9 N.	1·7 W.	7·4 N.	3·0 W.	6·8 N.	5·3 W.	4·5 N.	6·6 W.	0·5 N.	7·0 W.	2·1 N.	6·2 W.	

The first entry in this table (1·5 S.) implies that the average of the north components of the winds which blew in the month of June 1867 is −1·5, and the companion entry (12·5 W.) that the average east component for the same period is −12·5.

The average for the seven years of the north components of the wind is +2·1 miles per hour, and the average of the east components −6·2 miles per hour, which combined give a resultant wind from the direction N. 71° 17′ W. of velocity 6·5 miles per hour.

131. In order to exhibit the degree of persistency with which the winds blow in the normal direction, and with the normal force in the different months, we have constructed the figures 11 to 23 to represent the numbers in the preceding table. The form on which the figures are drawn is divided by thin red lines into squares, whose sides represent *one* mile per hour of velocity, and by thicker red lines into squares, whose sides are *five* miles. One of the intersections of these thicker lines is chosen for each month to represent calm, and is surrounded by four black dots; the component winds are taken along the intersecting lines, reckoning from the point of intersection as the *zero*—upward if north, downward if south, to the right if east, and to the left if west. Contemporaneous north and east components are indicated by a single dot, which is marked with the two last figures of the year to which it corresponds, and which represents by its direction and distance from the zero the direction and velocity respectively of the resultant wind of that year, for the particular month. Thus, in fig. 16, for the month of June and the year 1867, the point is taken 1·5 below and 12·5 to the left of the horizontal and vertical lines respectively which pass through the zero, and the direction and velocity of the resultant wind are S. 70° 12′ W., and 13·3 miles respectively. The normal wind of the month, being the resultant of the several years' winds in that month, is represented by a dot enclosed by a small circle, which dot is joined by a black line to the zero; and, with this dot as centre, circles of two and three miles radius are described. The extrusion of a point beyond the respective circles implies that for the corresponding year an abnormal wind blew from some direction exceeding in velocity two or three miles per hour. In the seven years' period no such monthly abnormal winds exceeding three miles per hour are found for the months October to May, nor any exceeding two miles per hour for December to March. The monthly resultant winds of the monsoon months, and those of June in particular, are subject to the most considerable variations. As compared with the normal wind for the several months of the seven years, June has five years in which the abnormal wind has a velocity exceeding two miles per hour, and four years exceeding three miles. July has five years exceeding two miles, and one year exceeding three miles. In April and August to November the numbers of years in which the abnormal exceeded two miles were 3, 4, 1, and 3 respectively; and in August and September the number of excesses over three miles were 1 and 2 respectively. Of the abnormals for the whole year, that of 1872 only somewhat exceeded one mile per hour. The years having the greatest number of monthly abnormal winds exceeding two miles per hour are 1871 and 1869. For the monsoon months, June to September, those of 1871 were all from a direction increasing the strength of the normal monsoon wind, and yet the rainfall of all those months was greatly in defect of the average. In July and August 1869 the effect of the abnormal winds was to reduce the strength of the normal monsoon wind, in the latter month to the extent of almost one half; the latter abnormal had a velocity of 6·3 miles, and it is the largest of any of the 84 monthly abnormals in the period.

132. *Annual variation of north and east components of the wind.*—The normal velocities of the north and east components of the wind for each day of the year have been found from the mean velocities for each day, by performing six smoothing operations, and afterwards taking 29 day means of the sixth smoothed means; the normal of a given day being thus the mean of its own, and of the 14 preceding and 14 following sixth smoothed means. The means and normals for each day of the year are shown in Tables 70 to 73.

TABLE 70.

SHOWING the MEAN NORTH COMPONENT of the WIND for each Day of the Year, deduced from Seven Years' Observations.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	+ 6·4	+ 8·6	+6·9	+6·7	+2·8	− 1·5	−6·7	−3·1	−1·6	+4·6	+5·2	+6·7
2	+ 6·8	+ 9·2	+7·9	+5·6	+2·8	− 2·7	−5·7	−5·6	−0·1	+4·7	+5·3	+5·0
3	+ 9·1	+ 6·6	+6·5	+4·9	+3·0	− 4·2	−5·9	−6·8	+0·7	+5·0	+5·5	+4
4	+11·3	+ 5·6	+6·0	+4·2	−0·4	− 7·9	−5·8	−4·2	+2·5	+5·3	+5·1	+5·3
5	+11·7	+ 6·3	+8·6	+4·1	+1·4	− 8·4	−4·5	−4·0	+2·3	+4·6	+6·6	+6·0
6	+10·0	+ 8·4	+8·4	+7·2	+1·6	− 5·9	−4·2	−3·6	−1·1	+4·3	+5·1	+6·5
7	+10·5	+ 8·4	+7·3	+5·6	+1·7	− 6·5	−4·5	−1·7	−1·6	+1·5	+2·7	+6·5
8	+ 9·5	+ 7·3	+5·9	+3·6	+0·8	−12·4	−5·9	−3·2	0·0	+0·3	+4·4	+5·0
9	+ 7·7	+ 7·4	+4·0	+6·1	−2·3	−11·0	−7·1	−3·2	+2·2	+4·2	+6·8	+5·3
10	+ 6·9	+ 6·9	+7·1	+5·8	−1·7	−10·3	−6·7	−3·3	+2·7	+6·2	+6·2	+7·3
11	+ 7·3	+ 6·7	+6·7	+2·2	+0·5	− 6·4	−5·7	−3·5	+1·2	+6·0	+5·4	+6·9
12	+ 8·1	+ 6·6	+6·8	+4·6	+2·1	− 4·5	−4·9	−3·9	−0·3	+5·8	+1·7	+5·2
13	+ 8·4	+ 7·2	+6·1	+5·8	+1·6	− 8·2	−6·5	−4·6	+0·1	+5·8	+2·8	+4·6
14	+ 5·4	+ 5·0	+8·5	+4·4	+0·6	− 7·5	−6·4	−5·4	−0·1	+6·2	+5·5	+5·3
15	+ 5·0	+ 7·5	+8·8	+4·9	−0·4	− 7·3	−6·6	−4·0	−2·0	+4·3	+5·8	+4·4
16	+ 8·9	+ 7·2	+8·9	+8·4	0·0	− 6·6	−2·1	−5·3	−4·6	+4·6	+5·5	+3·9
17	+ 7·3	+ 6·7	+7·2	+2·6	−0·5	− 8·0	−7·0	−5·9	−3·7	+2·2	+6·8	+5·1
18	+ 7·9	+ 7·9	+5·8	+4·0	−1·7	− 6·2	−4·9	−3·8	+1·0	+5·0	+6·5	+6·3
19	+ 9·0	+ 9·2	+4·2	+3·6	−0·1	− 6·1	−6·8	−3·6	+1·4	+4·8	+4·6	+5·1
20	+ 5·8	+10·1	+5·2	+1·6	−1·9	− 8·1	−6·7	−4·0	−0·2	+5·2	+6·2	+5·7
21	+ 7·0	+ 8·8	+6·2	+3·6	−1·4	− 7·1	−8·4	−4·3	−1·3	+1·6	+5·0	+7·7
22	+ 9·0	+ 7·4	+8·3	+5·3	+0·1	−16·6	−9·2	−2·5	−2·6	+2·6	+4·9	+5·8
23	+ 8·7	+ 8·7	+8·9	+5·5	+1·7	− 9·5	−8·9	−2·6	−1·9	+3·5	+4·8	+5·7
24	+ 9·5	+ 7·6	+8·3	+6·5	+2·5	− 8·5	−5·9	−1·7	−2·9	+5·6	+6·5	+3·9
25	+ 7·3	+ 8·3	+8·0	+7·1	+1·7	− 7·9	−6·3	+0·2	−1·7	+4·8	+5·4	+6·3
26	+ 5·6	+ 7·4	+6·0	+4·7	+1·0	− 8·4	−6·0	−0·5	+1·0	+3·7	+5·5	+6·9
27	+ 6·1	+ 4·8	+3·7	+1·5	+2·6	− 7·6	−7·3	−2·6	+2·2	+3·9	+5·7	+7·4
28	+ 6·2	+ 6·5	+2·8	+2·8	+1·1	− 7·2	−6·5	−0·8	+1·6	+6·1	+5·2	+7·0
29	+ 6·2		+4·1	+5·3	−1·1	− 5·3	−6·1	+1·8	+1·4	+6·9	+5·8	+7·6
30	+ 8·2		+4·5	+2·7	−2·6	− 6·9	−6·6	+1·7	+3·3	+5·5	+5·1	+7·4
31	+ 9·2		+7·5		−1·4		−7·6	+0·4		+4·6		+8·9

TABLE 71.

SHOWING the MEAN EAST COMPONENT of the WIND for each Day of the Year, deduced from Seven Years' Observations.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	−0·9	−2·5	−4·5	−5·8	−7·2	− 5·2	−15·6	−18·0	−12·4	−5·6	0·0	−0·2
2	−0·8	−2·6	−4·1	−6·2	−7·1	− 5·7	−16·3	−17·4	−10·5	−4·6	+0·6	−0·2
3	−2·3	−2·1	−5·4	−5·6	−5·4	− 5·3	−16·1	−17·5	− 9·3	−3·0	+0·3	+1·9
4	−2·8	−2·0	−4·5	−5·6	−6·7	− 0·4	−14·1	−18·2	− 8·5	−3·8	+0·9	+1·0
5	−3·7	−3·0	−3·9	−5·7	−7·8	− 2·8	−14·8	−16·6	−11·5	−4·2	+1·2	+1·0
6	−2·8	−2·5	−4·8	−6·2	−8·3	− 4·3	−15·3	−16·0	−11·0	−4·9	+1·5	+1·1
7	−2·8	−2·4	−5·3	−6·2	−7·7	− 4·5	−14·8	−16·4	−10·9	−2·2	+2·8	+0·7
8	−1·7	−2·5	−3·8	−6·8	−8·1	− 1·2	−14·7	−16·4	−10·4	−2·3	+2·1	+1·3
9	−0·7	−3·3	−4·1	−6·4	−7·7	− 2·8	−13·8	−15·9	− 9·4	−1·6	+1·9	+1·4
10	−1·5	−3·2	−4·7	−6·3	−7·7	− 8·4	−13·5	−14·1	− 9·9	−2·0	+2·1	+0·4
11	−1·0	−3·7	−5·1	−5·7	−8·3	− 6·2	−14·1	−14·2	−10·3	−1·1	+0·6	0·0
12	−1·6	−2·2	−5·1	−6·6	−8·6	− 9·5	−11·9	−12·4	− 9·4	−0·3	+1·8	+0·2
13	−1·7	−3·0	−5·4	−6·8	−8·8	− 8·4	−13·8	−14·3	− 9·3	+0·8	+1·3	−0·3
14	−0·8	−1·6	−6·4	−6·9	−7·1	− 9·7	−19·2	−16·4	− 8·8	+0·8	+0·2	+0·3
15	+0·1	−2·0	−7·0	−5·7	−8·8	− 9·8	−20·0	−17·0	− 9·1	−0·2	+0·4	+0·7
16	−0·2	−2·2	−5·4	−5·2	−8·4	−11·2	−17·7	−16·8	− 5·7	−0·8	+1·0	+1·6
17	−0·9	−3·1	−4·6	−6·4	−8·7	−12·8	−19·1	−15·8	− 3·1	−1·2	+2·2	+1·8
18	+0·1	−3·6	−3·9	−6·7	−7·2	−13·5	−21·3	−18·1	− 6·3	−0·5	+1·2	+0·3
19	−0·9	−4·5	−4·6	−7·6	−9·3	−13·8	−21·3	−16·9	− 7·2	−0·8	+2·1	+1·2
20	−1·7	−4·7	−5·7	−6·3	−8·8	−13·4	−20·0	−15·2	− 5·9	−0·5	+1·0	−0·4
21	−2·8	−3·2	−6·4	−7·2	−7·8	−14·5	−17·2	−16·5	− 1·1	−0·2	+1·0	−0·5
22	−2·7	−3·7	−6·6	−7·4	−8·0	−15·4	−19·2	−14·9	− 6·9	−0·9	+0·8	−1·4
23	−2·8	−4·1	−6·5	−7·1	−9·2	−18·0	−19·5	−13·5	− 4·3	0·0	+2·1	−1·4
24	−2·8	−3·4	−6·4	−7·7	−9·0	−12·0	−20·9	−13·9	− 4·7	+0·3	+2·4	0·0
25	−1·9	−3·6	−4·7	−7·6	−8·9	−13·1	−20·3	−13·8	− 6·6	−0·3	+1·1	+0·6
26	−1·2	−2·7	−5·0	−7·5	−8·0	−12·7	−18·6	−12·8	− 8·1	−0·9	+0·5	0·0
27	0·0	−2·2	−5·7	−7·1	−8·1	−16·1	−19·8	−12·6	− 5·7	−0·2	+2·6	−0·8
28	−1·5	−2·9	−5·2	−7·5	−7·3	−18·6	−21·2	−14·0	− 3·8	−0·9	+2·5	−0·7
29	−2·3		−5·6	−6·9	−6·7	−17·6	−20·2	−12·1	− 2·8	−1·5	+1·2	−1·1
30	−3·9		−5·6	−6·4	−7·4	−14·9	−20·2	−10·6	− 4·7	−0·8	+1·6	−1·3
31	−2·4		−6·9		−7·0		−19·4	−11·5		+0·5		−2·6

TABLE 72.

SHOWING the NORMAL NORTH COMPONENT of the WIND for each Day of the Year, deduced from Seven Years' Observations.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	+7·4	+7·3	+7·3	+5·1	+2·5	−3·6	−6·5	−5·5	−1·1	+2·2	+4·7	+5·6
2	+7·4	+7·3	+7·4	+5·1	+2·3	−3·8	−6·5	−5·5	−1·0	+2·4	+4·8	+5·5
3	+7·5	+7·3	+7·4	+5·0	+2·2	−4·0	−6·5	−5·4	−1·0	+2·6	+4·8	+5·5
4	+7·6	+7·3	+7·3	+4·9	+2·0	−4·2	−6·5	−5·3	−0·9	+2·7	+4·9	+5·5
5	+7·6	+7·4	+7·2	+4·8	+1·9	−4·4	−6·5	−5·2	−0·7	+2·9	+5·0	+5·5
6	+7·7	+7·4	+7·1	+4·7	+1·7	−4·7	−6·4	−5·0	−0·6	+3·1	+5·0	+5·5
7	+7·7	+7·4	+7·0	+4·6	+1·5	−5·0	−6·5	−4·9	−0·6	+3·2	+5·1	+5·6
8	+7·8	+7·4	+7·0	+4·6	+1·4	−5·3	−6·5	−4·8	−0·6	+3·4	+5·1	+5·6
9	+7·9	+7·4	+6·9	+4·6	+1·2	−5·6	−6·4	−4·6	−0·6	+3·6	+5·2	+5·6
10	+8·0	+7·5	+6·8	+4·7	+1·1	−6·0	−6·4	−4·5	−0·7	+3·8	+5·2	+5·6
11	+8·0	+7·5	+6·7	+4·7	+1·0	−6·3	−6·4	−4·3	−0·7	+4·0	+5·2	+5·6
12	+8·0	+7·5	+6·6	+4·8	+0·9	−6·6	−6·3	−4·1	−0·7	+4·1	+5·2	+5·6
13	+7·9	+7·5	+6·5	+4·8	+0·8	−6·8	−6·3	−3·9	−0·7	+4·2	+5·2	+5·7
14	+7·9	+7·5	+6·4	+4·7	+0·7	−7·0	−6·3	−3·7	−0·7	+4·3	+5·2	+5·7
15	+7·8	+7·4	+6·3	+4·6	+0·6	−7·2	−6·3	−3·4	−0·6	+4·4	+5·2	+5·8
16	+7·9	+7·4	+6·3	+4·5	+0·4	−7·4	−6·3	−3·2	−0·5	+4·5	+5·2	+5·9
17	+7·9	+7·3	+6·2	+4·4	+0·3	−7·5	−6·3	−3·0	−0·3	+4·5	+5·3	+5·9
18	+7·9	+7·3	+6·2	+4·3	+0·1	−7·5	−6·3	−2·8	−0·1	+4·5	+5·3	+6·0
19	+7·8	+7·4	+6·1	+4·2	0·0	−7·5	−6·3	−2·6	+0·1	+4·5	+5·3	+6·1
20	+7·7	+7·4	+6·1	+4·1	−0·2	−7·4	−6·4	−2·5	+0·3	+4·5	+5·3	+6·2
21	+7·5	+7·4	+6·0	+4·0	−0·5	−7·4	−6·4	−2·5	+0·5	+4·6	+5·3	+6·4
22	+7·4	+7·3	+5·9	+3·8	−0·8	−7·2	−6·3	−2·4	+0·7	+4·7	+5·3	+6·5
23	+7·4	+7·2	+5·9	+3·7	−1·0	−7·1	−6·3	−2·4	+0·8	+4·8	+5·4	+6·7
24	+7·4	+7·2	+5·9	+3·5	−1·3	−6·9	−6·1	−2·3	+0·8	+4·8	+5·4	+6·8
25	+7·4	+7·2	+5·8	+3·3	−1·6	−6·8	−6·0	−2·2	+0·9	+4·8	+5·4	+6·9
26	+7·4	+7·2	+5·8	+3·2	−2·0	−6·8	−5·9	−2·0	+1·0	+4·8	+5·5	+7·0
27	+7·4	+7·2	+5·7	+3·0	−2·3	−6·7	−5·9	−1·8	+1·2	+4·8	+5·6	+7·0
28	+7·4	+7·3	+5·6	+2·9	−2·6	−6·7	−5·8	−1·7	+1·5	+4·7	+5·6	+7·1
29	+7·4		+5·5	+2·7	−2·9	−6·6	−5·7	−1·5	+1·7	+4·7	+5·6	+7·2
30	+7·4		+5·4	+2·6	−3·1	−6·6	−5·7	−1·3	+1·9	+4·7	+5·7	+7·2
31	+7·4		+5·2		−3·3		−5·6	−1·2		+4·7		+7·3
Monthly Means	+7·6	+7·4	+6·4	+4·2	0·0	−6·2	−6·2	−3·4	0·0	+4·0	+5·2	+6·1

TABLE 73.

SHOWING the NORMAL EAST COMPONENT of the WIND for each Day of the Year, deduced from Seven Years' Observations.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	−1·1	−2·2	−4·1	−5·9	−7·4	− 6·9	−14·7	−17·9	−11·9	−3·7	+0·4	+1·1
2	−1·2	−2·3	−4·2	−6·0	−7·5	− 6·9	−14·9	−17·7	−11·6	−3·5	+0·4	+1·1
3	−1·2	−2·4	−4·3	−6·0	−7·5	− 7·1	−15·2	−17·6	−11·2	−3·3	+0·5	+1·0
4	−1·2	−2·4	−4·3	−6·1	−7·6	− 7·2	−15·4	−17·5	−10·8	−3·2	+0·6	+1·0
5	−1·2	−2·5	−4·4	−6·1	−7·6	− 7·4	−15·6	−17·4	−10·5	−3·0	+0·6	+1·0
6	−1·2	−2·6	−4·4	−6·1	−7·7	− 7·6	−15·8	−17·3	−10·2	−2·9	+0·7	+1·0
7	−1·3	−2·6	−4·5	−6·2	−7·7	− 7·8	−16·0	−17·2	− 9·8	−2·7	+0·7	+0·9
8	−1·3	−2·7	−4·6	−6·2	−7·7	− 8·0	−16·2	−17·0	− 9·5	−2·6	+0·8	+0·8
9	−1·4	−2·7	−4·7	−6·3	−7·8	− 8·1	−16·4	−16·8	− 9·2	−2·4	+0·9	+0·7
10	−1·5	−2·8	−4·8	−6·3	−7·8	− 8·3	−16·6	−16·6	− 8·9	−2·2	+0·9	+0·7
11	−1·6	−2·9	−4·8	−6·4	−7·9	− 8·5	−16·8	−16·4	− 8·7	−2·0	+1·0	+0·6
12	−1·6	−2·9	−4·9	−6·5	−7·9	− 8·7	−17·0	−16·2	− 8·5	−1·8	+1·1	+0·5
13	−1·6	−2·9	−5·0	−6·5	−7·9	− 9·0	−17·1	−15·9	− 8·3	−1·7	+1·2	+0·4
14	−1·6	−3·0	−5·1	−6·6	−7·9	− 9·3	−17·2	−15·7	− 8·0	−1·5	+1·3	+0·4
15	−1·6	−3·0	−5·2	−6·6	−7·9	− 9·7	−17·3	−15·4	− 7·7	−1·4	+1·3	+0·3
16	−1·6	−3·1	−5·2	−6·6	−7·9	−10·1	−17·5	−15·2	− 7·5	−1·3	+1·4	+0·2
17	−1·7	−3·1	−5·3	−6·7	−7·9	−10·4	−17·6	−15·0	− 7·3	−1·1	+1·4	+0·1
18	−1·7	−3·2	−5·3	−6·7	−7·9	−10·8	−17·7	−14·8	− 7·1	−1·0	+1·4	+0·1
19	−1·7	−3·3	−5·4	−6·7	−7·8	−11·3	−17·8	−14·6	− 6·9	−0·9	+1·4	0·0
20	−1·7	−3·4	−5·4	−6·8	−7·7	−11·7	−17·9	−14·3	− 6·6	−0·7	+1·4	−0·1
21	−1·7	−3·4	−5·5	−6·8	−7·6	−12·1	−17·9	−14·1	− 6·4	−0·5	+1·3	−0·2
22	−1·7	−3·5	−5·5	−6·9	−7·4	−12·5	−18·0	−13·9	− 6·2	−0·4	+1·3	−0·4
23	−1·7	−3·6	−5·6	−6·9	−7·2	−12·9	−18·1	−13·7	− 5·9	−0·3	+1·3	−0·5
24	−1·7	−3·6	−5·6	−7·0	−7·1	−13·2	−18·2	−13·6	− 5·7	−0·1	+1·2	−0·6
25	−1·8	−3·7	−5·7	−7·0	−6·9	−13·5	−18·3	−13·4	− 5·4	0·0	+1·2	−0·7
26	−1·8	−3·7	−5·7	−7·1	−6·8	−13·7	−18·3	−13·3	− 5·1	+0·1	+1·2	−0·8
27	−1·9	−3·8	−5·8	−7·1	−6·7	−13·9	−18·4	−13·1	− 4·8	+0·2	+1·2	−0·8
28	−2·0	−4·0	−5·8	−7·2	−6·7	−14·0	−18·3	−13·0	− 4·5	+0·2	+1·1	−0·9
29	−2·0		−5·8	−7·3	−6·7	−14·2	−18·2	−12·8	− 4·2	+0·2	+1·1	−0·9
30	−2·1		−5·8	−7·3	−6·7	−14·5	−18·1	−12·5	− 3·9	+0·3	+1·1	−1·0
31	−2·2		−5·9		−6·7		−18·0	−12·3		+0·3		−1·1
Monthly Means	−1·6	−3·0	−5·1	−6·6	−7·5	−10·3	−17·1	−15·2	− 7·7	−1·4	+1·0	+0·1

The means are curved in black ink and the normals in red in figs. 6 and 7. The latter are also curved (in fig. 10) in a form to exhibit the resultant direction and velocity of the normal wind of each day, and the variations from day to day throughout the year; that is, in the manner described in paragraph 131.

133. On fig. 10 we remark that from the 1st January to the 18th May—and neglecting the consideration of small irregularities, such as the movement to northward that occurs between the 1st and 26th January—the velocity of the resultant wind is nearly constant and about eight miles per hour, whilst the direction moves round from N. 8° W. to due west; the movement at first is slow and nearly uniform, more rapid during March and April, and still more so in May. The normal directions, on the first day of each month, from February to May, are N. 17° W., N. 29° W., N. 49° W., and N. 71° W. respectively. After the 18th May,

the left-handed rotation of the wind continuing, the velocity slightly diminishes till the 26th May, when it has become 7·1 miles, and the direction is then the same (S. 72° W.) as on 27th July, when the monsoon wind is at its maximum of 19·3 miles per hour. The left-handed rotation continues till 12th June, when the normal wind has acquired its most southerly direction (S. 52° W.), and the reverse rotation which follows lasts till 16th November, when the direction is N. 15° E., and after this date the left-handed rotation is resumed. Thus the normal winds of every part of the year lie within the 143° of the compass, enclosed between the directions S. 52° W. and N. 15° E., going through west. From the end of May till 27th July the west component of the wind continuously increases, and then it diminishes till 16th November; meanwhile the south component increases till 17th June, when it has a velocity of 7·5 miles, diminishes slightly for a week, and then remains nearly unchanged till the 23rd July. The normal wind of 27th July is gradually changed to that of 16th November by increments of north-east wind, alternating with increments from nearly due east or intermediate directions; north-east increments are received during the periods 27th July to 19th August, 24th to 31st August, 15th to 22nd September, 26th September to 16th October, 20th to 23rd October, and 1st to 11th November. In the months August and September the hourly velocity receives these increments at the rate of about a quarter of a mile per day, but the rate diminishes very much in October, and still more in November; the increments from a more easterly direction are received during the periods intervening between those of the north-east increments and from the 11th to 16th November, that of 31st August to 15th September being of greatest duration. On the 5th October occurs the lowest normal wind of the year (4·2 miles). From the 16th November to 12th December the normal wind is almost constant, receiving only an aggregate increment of one mile per hour of wind from west-north-west; further increments from north-west, in the remaining days of December, bring back the normal wind with which the year commences. The general form of the curve is that of a somewhat irregular figure of eight, with its length axis in the direction N.E. by N. and S.W. by S.; the upper loop having a left-handed and the lower a right-handed rotation, and the intersection being almost due westward. The year is thus divided into two unequal periods, from 21st May to 16th September, when the normal wind is southerly, and from 16th September to 21st May, when, with the exception of only four days, it is northerly.

The very considerable upward inflexion of the east component curve (fig. 7), with its middle point about the 6th June, is doubtless largely contributed to by the frequent heavy squalls which accompany the Elephanta storms that occur at the commencement of the monsoon. These squalls come from the direction of the hills that lie in the south-east quadrant from Colába, where it is probable that they originate with the violent thunderstorms which intermittingly rage in the district, and with the heavy rain that is concurrently discharged. In the black curves of figs. 6 and 7 their effects are of course more strongly marked than in the normal curves, by large departures—southward of the mean north components and eastward of the mean east components—from the general course of the curves. But there is too much persistency about the south-east component of the wind of June to allow it to be attributed wholly to the Elephanta storms; and it will be seen further on that at Goa, as at Bombay, the normal wind of May is changed into that of June by the addition of a south-east component.

134. The period from about a week before to a week after (more or less) the end of November is one of remarkable quiescence in all the elements observed, the corresponding

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portions of the normal curves of barometric pressure, temperature, pressure of vapour, and north and east components of the wind, all approximating closely to horizontal straight lines.

135. *Annual variation affected by systematic oscillations of short period.*—The reason why, in the case of the wind, we choose for our daily normals 29-day means rather than 15-day means is that it was found that the curves of 15-day means, both of the north and east components, exhibited oscillations—of period varying in different seasons from about a month to a few days only—which impressed themselves in a marked manner upon the great movements of the year, and thus deprived the curves of the most essential quality of normal curves; and the 29-day means pretty completely eliminating these oscillations, it was possible by adopting them as normals, and by taking 15-day means of the daily abnormals, to give to the oscillations a separate exhibition. This appears numerically in the Tables 74 and 75, and graphically in figs. 8 and 9, and from the systematic character of the curves it would seem to be well deserving of the attention of the theoretical speculator.

TABLE 74.

FIFTEEN-DAY MEANS, for each Day of the Year, of the DAILY ABNORMALS of the NORTH COMPONENT of the WIND.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	+1·08	−0·10	−0·01	−0·29	+0·51	+0·32	+0·19	+0·06	+0·54	+0·26	+0·18	+0·14
2	+1·11	−0·09	−0·21	0·00	+0·08	−0·26	+0·25	+0·17	+0·59	+0·55	+0·29	+0·04
3	+1·04	−0·01	−0·29	+0·06	−0·35	−0·74	+0·30	+0·26	+0·71	+0·88	+0·43	+0·16
4	+0·97	+0·02	−0·31	+0·02	−0·49	−1·08	+0·46	+0·42	+0·89	+1·01	+0·51	+0·25
5	+0·98	+0·04	−0·37	+0·19	−0·31	−1·18	+0·61	+0·48	+0·86	+1·07	+0·18	+0·20
6	+0·98	+0·10	−0·40	+0·35	−0·25	−1·44	+0·63	+0·45	+0·69	+1·16	−0·13	+0·16
7	+0·80	−0·12	−0·10	+0·38	−0·50	−1·51	+0·60	+0·40	+0·53	+1·30	−0·17	+0·12
8	+0·51	−0·24	+0·12	+0·25	−0·58	−1·66	+0·60	+0·49	+0·33	+1·18	−0·12	+0·06
9	+0·64	−0·33	+0·32	+0·07	−0·62	−1·74	+0·56	+0·32	+0·09	+1·03	−0·14	−0·15
10	+0·65	−0·50	+0·35	−0·09	−0·71	−1·85	+0·46	+0·13	−0·19	+0·77	−0·07	−0·17
11	+0·54	−0·42	+0·38	−0·10	−0·88	−1·76	+0·52	+0·16	−0·14	+0·64	−0·04	−0·11
12	+0·37	−0·18	+0·34	−0·10	−0·74	−1·42	+0·45	+0·06	+0·06	+0·49	−0·10	−0·16
13	−0·03	+0·07	+0·19	−0·22	−0·81	−1·20	+0·29	−0·12	+0·13	+0·43	−0·14	−0·23
14	−0·22	+0·10	+0·12	−0·41	−0·87	−1·10	+0·01	−0·33	+0·04	+0·14	−0·17	−0·21
15	−0·29	+0·04	+0·26	−0·38	−0·82	−0·96	−0·31	−0·55	−0·11	+0·11	−0·04	−0·33
16	−0·31	+0·15	+0·54	−0·19	−0·59	−0·65	−0·53	−0·67	−0·33	+0·23	−0·02	−0·35
17	−0·15	+0·18	+0·56	−0·09	−0·11	−0·40	−0·47	−0·72	−0·76	+0·25	−0·06	−0·53
18	−0·09	+0·29	+0·36	+0·09	+0·31	−0·18	−0·47	−0·67	−1·16	+0·09	−0·12	−0·68
19	−0·17	+0·36	+0·37	+0·36	+0·53	−0·29	−0·52	−0·63	−1·28	−0·12	−0·14	−0·77
20	−0·26	+0·26	+0·21	+0·28	+0·78	−0·48	−0·72	−0·69	−1·25	−0·29	+0·11	−0·72
21	−0·37	+0·23	+0·05	+0·20	+0·98	−0·38	−0·75	−0·59	−1·29	−0·31	+0·25	−0·65
22	−0·29	+0·36	−0·18	+0·39	+1·19	−0·33	−0·76	−0·25	−1·35	−0·29	+0·24	−0·59
23	−0·05	+0·40	−0·40	+0·38	+1·29	−0·33	−0·80	−0·01	−1·14	−0·23	+0·17	−0·49
24	+0·01	+0·35	−0·43	+0·47	+1·44	−0·40	−0·88	+0·23	−0·71	−0·24	+0·22	−0·25
25	+0·14	+0·30	−0·39	+0·63	+1·63	−0·31	−0·81	+0·40	−0·33	−0·10	+0·08	−0·26
26	+0·27	+0·36	−0·33	+0·71	+1·83	−0·35	−0·91	+0·53	−0·24	−0·10	−0·04	−0·32
27	+0·14	+0·32	−0·21	+0·61	+1·82	−0·40	−0·97	+0·61	−0·16	−0·07	−0·01	−0·15
28	+0·15	+0·16	−0·20	+0·74	+1·68	−0·23	−0·92	+0·60	−0·02	−0·10	−0·04	+0·14
29	+0·11		−0·26	+0·76	+1·48	−0·10	−0·70	+0·62	+0·19	+0·21	+0·05	+0·32
30	+0·07		−0·26	+0·67	+1·34	−0·01	−0·42	+0·59	+0·29	+0·36	+0·14	+0·53
31	+0·05		−0·39		+1·05		−0·03	+0·54		+0·29		+0·78

TABLE 75.

FIFTEEN-DAY MEANS, for each Day of the Year, of the DAILY ABNORMALS of the EAST COMPONENT of the WIND.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	−0·50	+0·04	+0·11	+0·15	+0·09	+1·56	−0·40	−0·59	+0·27	−0·57	−0·06	+0·17
2	−0·54	+0·01	+0·17	+0·08	+0·14	+2·05	−0·30	−0·39	+0·28	−0·58	+0·03	+0·13
3	−0·59	−0·06	+0·20	+0·03	+0·19	+2·12	−0·12	−0·21	+0·19	−0·49	+0·17	+0·16
4	−0·56	−0·24	+0·17	+0·07	+0·19	+2·37	−0·01	+0·03	+0·05	−0·23	+0·17	+0·13
5	−0·58	−0·22	+0·16	+0·02	+0·15	+2·35	+0·53	+0·47	+0·06	−0·07	+0·29	+0·01
6	−0·58	−0·20	+0·06	−0·01	+0·11	+2·40	+1·06	+0·71	−0·06	+0·05	+0·41	−0·12
7	−0·50	+0·01	−0·13	−0·05	+0·14	+2·42	+1·14	+0·80	−0·25	+0·11	+0·42	−0·14
8	−0·29	+0·09	−0·32	+0·08	+0·03	+2·42	+0·99	+0·80	−0·39	+0·24	+0·34	−0·14
9	−0·21	+0·17	−0·31	+0·16	−0·02	+2·24	+1·04	+0·77	−0·24	+0·40	+0·35	+0·03
10	−0·18	+0·19	−0·27	+0·20	−0·09	+2·00	+1·03	+0·70	−0·03	+0·47	+0·39	+0·23
11	+0·01	+0·15	−0·09	+0·17	−0·18	+1·70	+0·85	+0·47	−0·14	+0·48	+0·39	+0·19
12	+0·17	+0·03	−0·03	+0·08	−0·34	+1·07	+0·54	+0·36	−0·32	+0·53	+0·43	+0·27
13	+0·33	−0·02	−0·08	+0·08	−0·39	+0·65	+0·34	+0·25	−0·20	+0·62	+0·37	+0·25
14	+0·36	−0·01	−0·11	+0·06	−0·36	+0·27	+0·36	0·00	+0·21	+0·78	+0·29	+0·22
15	+0·39	−0·04	−0·13	+0·03	−0·40	−0·15	+0·20	−0·12	+0·23	+0·72	+0·12	+0·17
16	+0·34	−0·09	−0·24	+0·05	−0·51	−0·61	+0·01	−0·15	+0·39	+0·72	+0·08	+0·08
17	+0·21	−0·04	−0·33	+0·01	−0·63	−0·89	−0·35	−0·23	+0·47	+0·69	+0·09	+0·07
18	+0·20	−0·01	−0·27	−0·03	−0·78	−0·86	−0·69	−0·42	+0·45	+0·66	+0·01	+0·18
19	+0·21	+0·11	−0·21	−0·10	−0·83	−0·94	−0·89	−0·54	+0·35	+0·54	−0·01	+0·27
20	+0·34	+0·17	−0·19	−0·09	−0·87	−1·03	−1·38	−0·75	+0·35	+0·41	+0·04	+0·30
21	+0·38	+0·24	−0·13	−0·10	−0·86	−1·37	−1·79	−0·93	+0·47	+0·17	+0·12	+0·36
22	+0·31	+0·13	−0·02	−0·06	−0·91	−1·57	−1·79	−0·84	+0·61	−0·10	+0·20	+0·36
23	+0·08	+0·07	+0·12	−0·06	−0·90	−1·59	−1·75	−0·61	+0·66	−0·26	+0·29	+0·31
24	−0·04	−0·06	+0·06	−0·13	−0·88	−1·58	−1·83	−0·52	+0·42	−0·27	+0·23	+0·12
25	−0·11	−0·07	+0·02	−0·13	−0·72	−1·52	−1·74	−0·50	+0·07	−0·30	+0·09	+0·02
26	−0·25	−0·02	−0·10	+0·01	−0·69	−1·40	−1·47	−0·21	+0·07	−0·32	+0·15	+0·03
27	−0·29	+0·04	−0·12	+0·13	−0·47	−1·15	−1·23	+0·07	+0·05	−0·34	+0·10	−0·12
28	−0·25	+0·07	−0·07	+0·08	+0·05	−0·98	−1·13	+0·29	−0·08	−0·34	+0·13	−0·20
29	−0·21		+0·02	+0·06	+0·38	−0·78	−1·13	+0·37	−0·57	−0·33	+0·16	−0·35
30	−0·14		+0·08	+0·10	+0·64	−0·51	−0·96	+0·38	−0·48	−0·24	+0·19	−0·39
31	−0·05		+0·14		+0·99		−0·81	+0·30		−0·12		−0·43

136. *Diurnal variation of north and east components of wind.*—Table 76 shows, for each month, for the winter and summer half years and for the whole year, the mean north and east components of the wind at each hour of the day; and Table 77 shows the excesses of the north and east components of the wind respectively, at each hour of the day, above the mean component for the 24 hours, deduced from seven years' observations.

TABLE 76.

Component.	June.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		April to September.		October to March.		Year.	
	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.
Hours.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
0 to 1	−7·6	− 8·5	−7·4	−16·9	−4·2	−14·9	−1·1	− 7·1	+2·9	+ 0·6	+3·2	+3·6	+ 4·3	+2·3	+ 6·3	+0·4	+ 5·7	− 1·0	+ 5·4	− 3·6	+4·9	− 4·6	−0·2	− 5·5	−2·6	− 9·6	+ 4·6	+ 0·4	+1·0	− 4·6
1 to 2	−7·2	− 8·4	−7·0	−17·5	−4·0	−15·1	−0·8	− 6·9	+2·5	+ 1·5	+3·4	+4·7	+ 4·0	+3·2	+ 5·8	+1·0	+ 5·5	− 0·2	+ 5·6	− 3·1	+4·8	− 3·6	−0·3	− 5·4	−2·4	− 9·5	+ 4·5	+ 1·2	+1·0	− 4·1
2 to 3	−7·2	− 8·1	−6·9	−17·6	−4·0	−15·0	−1·1	− 6·5	+2·3	+ 2·1	+3·8	+5·6	+ 3·9	+4·0	+ 5·8	+1·4	+ 5·6	+ 0·1	+ 5·7	− 2·5	+4·2	− 2·6	−0·3	− 4·7	−2·5	− 9·1	+ 4·5	+ 1·8	+1·0	− 3·7
3 to 4	−7·2	− 7·9	−7·0	−17·3	−3·9	−15·3	−1·0	− 6·4	+2·4	+ 2·7	+4·6	+6·4	+ 4·6	+4·7	+ 6·0	+2·0	+ 5·9	+ 0·5	+ 5·7	− 1·1	+3·5	− 1·4	−0·1	− 4·2	−2·6	− 8·7	+ 4·9	+ 2·5	+1·1	− 3·1
4 to 5	−6·8	− 7·8	−6·4	−17·7	−3·6	−14·6	−1·4	− 5·5	+2·7	+ 2·9	+4·9	+7·0	+ 5·0	+5·3	+ 6·2	+2·7	+ 6·0	+ 1·3	+ 5·4	− 0·1	+3·0	− 0·4	−0·1	− 3·5	−2·5	− 8·3	+ 5·0	+ 3·2	+1·2	− 2·6
5 to 6	−6·8	− 7·0	−5·7	−17·5	−3·5	−14·7	−1·7	− 4·6	+2·6	+ 3·5	+5·3	+7·5	+ 5·3	+5·9	+ 6·4	+3·0	+ 5·9	+ 1·9	+ 5·0	+ 1·4	+2·4	+ 0·5	−0·3	− 2·9	−2·6	− 7·7	+ 5·1	+ 3·8	+1·3	− 2·0
6 to 7	−6·7	− 6·4	−6·3	−16·4	−3·1	−14·0	−1·6	− 4·0	+2·5	+ 4·3	+5·1	+8·0	+ 5·3	+6·4	+ 5·9	+3·9	+ 5·5	+ 2·9	+ 4·2	+ 2·5	+2·0	+ 1·1	−0·5	− 2·5	−2·7	− 7·0	+ 4·8	+ 4·7	+1·0	− 1·2
7 to 8	−7·3	− 6·6	−6·5	−16·3	−3·4	−14·0	−1·8	− 3·4	+2·5	+ 4·9	+4·6	+9·0	+ 4·8	+6·9	+ 5·5	+4·6	+ 5·3	+ 4·0	+ 3·9	+ 2·9	+1·9	+ 1·4	−0·6	− 2·4	−3·0	− 6·9	+ 4·4	+ 5·4	+0·7	− 0·8
8 to 9	−7·1	− 6·8	−6·0	−16·5	−3·0	−14·0	−1·7	− 3·3	+2·4	+ 5·1	+4·4	+8·6	+ 4·5	+7·4	+ 5·5	+5·0	+ 5·0	+ 4·5	+ 4·1	+ 2·4	+1·8	+ 0·1	−0·9	− 3·5	−2·8	− 7·3	+ 4·3	+ 5·5	+0·7	− 0·9
9 to 10	−7·4	− 8·0	−6·1	−17·0	−3·1	−14·1	−1·8	− 5·0	+2·4	+ 4·1	+3·7	+7·9	+ 4·4	+6·8	+ 5·6	+4·5	+ 5·0	+ 4·6	+ 4·5	+ 0·7	+1·7	− 2·8	−0·9	− 5·7	−2·9	− 8·8	+ 4·3	+ 4·8	+0·7	− 2·0
10 to 11	−7·6	−10·1	−6·4	−17·6	−3·4	−14·6	−1·8	− 6·4	+1·9	+ 1·6	+2·6	+5·5	+ 3·6	+4·6	+ 5·2	+2·5	+ 4·7	+ 1·5	+ 4·4	− 3·5	+2·3	− 7·2	−0·4	− 8·4	−2·9	−10·7	+ 3·7	+ 2·0	+0·4	− 4·4
11 to 12	−7·4	−11·3	−6·2	−18·2	−3·3	−15·3	−0·9	− 8·7	+2·6	− 2·6	+2·6	+2·7	+ 3·6	+1·4	+ 5·7	−1·4	+ 5·7	− 3·6	+ 5·5	− 8·1	+3·3	−10·3	+0·1	−10·2	−2·4	−12·3	+ 4·3	− 1·9	+0·9	− 7·1
12 to 13	−7·6	−12·4	−5·9	−18·4	−3·0	−16·7	−0·2	−10·2	+4·3	− 6·4	+3·0	−1·3	+ 4·4	−2·6	+ 7·0	−5·5	+ 6·7	− 8·1	+ 6·3	−11·6	+4·5	−12·8	+0·5	−12·4	−2·0	−13·8	+ 5·3	− 5·8	+1·7	− 9·8
13 to 14	−7·3	−13·5	−6·1	−18·8	−2·9	−16·8	+0·2	−11·3	+5·6	− 8·7	+3·9	−5·1	+ 5·2	−5·4	+ 8·3	−8·2	+ 7·9	−10·3	+ 7·6	−13·2	+5·9	−14·4	+1·2	−13·5	−1·5	−14·7	+ 6·4	− 8·2	+2·5	−11·5
14 to 15	−7·3	−14·5	−5·7	−18·8	−2·9	−17·2	+1·2	−12·1	+7·2	−10·1	+5·2	−7·2	+ 6·4	−7·8	+ 9·5	−9·7	+ 9·1	−11·4	+ 9·0	−14·0	+6·7	−15·4	+2·0	−14·7	−1·0	−15·4	+ 7·7	− 9·7	+3·4	−12·5
15 to 16	−6·8	−14·4	−5·8	−18·7	−2·4	−17·3	+1·9	−12·2	+8·0	−10·3	+6·5	−8·5	+ 7·5	−8·8	+10·7	−9·7	+10·6	−11·6	+ 9·9	−14·3	+7·4	−15·1	+2·3	−14·7	−0·6	−15·4	+ 8·9	−10·1	+4·1	−12·7
16 to 17	−6·7	−13·8	−5·7	−18·6	−2·1	−16·8	+2·2	−11·7	+9·0	− 9·4	+7·8	−8·3	+ 8·6	−8·5	+12·0	−9·3	+11·7	−10·6	+10·4	−13·3	+8·2	−15·0	+2·5	−14·4	−0·3	−15·1	+ 9·9	− 9·5	+4·8	−12·3
17 to 18	−6·9	−13·4	−6·0	−18·4	−2·1	−16·5	+1·8	−11·1	+9·0	− 7·5	+9·1	−6·7	+ 9·7	−7·6	+12·7	−8·1	+12·1	− 9·5	+ 9·9	−11·8	+7·7	−13·3	+2·2	−12·8	−0·6	−14·2	+10·4	− 8·5	+4·9	−11·4
18 to 19	−6·5	−12·1	−6·2	−17·8	−2·1	−15·5	+1·4	− 9·5	+8·7	− 5·8	+9·9	−5·0	+10·7	−6·4	+13·2	−7·0	+12·3	− 8·2	+ 9·5	− 9·7	+7·1	−10·9	+1·9	−11·0	−0·7	−12·8	+10·7	− 7·0	+5·0	− 9·9
19 to 20	−7·3	−10·9	−6·6	−17·2	−2·4	−15·0	+0·7	− 8·3	+7·8	− 3·6	+9·6	−3·8	+10·8	−5·4	+13·0	−6·3	+11·8	− 6·9	+ 8·4	− 7·8	+5·6	− 8·2	+1·7	− 9·0	−1·4	−11·4	+10·2	− 5·6	+4·4	− 8·5
20 to 21	−7·3	−10·1	−6·5	−17·0	−2·8	−14·4	+0·3	− 7·5	+6·2	− 2·3	+8·0	−1·8	+ 9·4	−3·3	+11·2	−4·1	+10·1	− 5·4	+ 6·8	− 6·1	+5·0	− 6·4	+0·8	− 7·7	−1·8	−10·5	+ 8·6	− 3·8	+3·4	− 7·2
21 to 22	−7·5	− 9·5	−6·6	−17·0	−3·3	−14·1	−0·2	− 7·1	+5·2	− 1·1	+6·4	+0·3	+ 7·5	−1·0	+ 8·8	−2·1	+ 7·9	− 3·0	+ 5·3	− 4·7	+4·9	− 5·9	+0·7	− 7·1	−2·0	−10·1	+ 6·9	− 1·9	+2·4	− 6·0
22 to 23	−7·3	− 9·0	−7·1	−17·1	−3·6	−14·1	−0·5	− 6·9	+4·4	− 0·1	+4·9	+1·5	+ 6·2	+0·3	+ 7·6	−0·8	+ 6·6	− 1·6	+ 4·9	− 4·1	+4·8	− 5·6	+0·2	− 6·8	−2·2	− 9·9	+ 5·8	− 0·8	+1·8	− 5·4
23 to 24	−7·4	− 8·6	−7·0	−16·7	−3·8	−14·1	−0·7	− 6·9	+3·3	+ 0·5	+3·9	+2·7	+ 4·9	+1·5	+ 6·7	−0·1	+ 6·0	− 1·2	+ 4·9	− 4·0	+4·6	− 5·1	−0·1	− 5·9	−2·4	− 9·5	+ 5·0	− 0·1	+1·3	− 4·8
Means for seven years	−7·2	−10·0	−6·4	−17·5	−3·2	−15·2	−0·4	− 7·6	+4·5	− 1·4	+5·3	+1·4	+ 6·0	+0·2	+ 7·9	−1·7	+ 7·4	− 3·0	+ 6·3	− 5·3	+4·5	− 6·6	+0·5	− 7·9	−2·0	−10·8	+ 6·3	− 1·6	+2·1	− 6·2

TABLE 77.

Component.	June.		July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		April to September.		October to March.		Year.	
	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.	Nor.	East.
Hours.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
0 to 1	−0·4	+1·5	−1·0	+0·6	−1·0	+0·3	−0·7	+0·5	−1·6	+2·0	−2·1	+2·2	−1·7	+2·1	−1·6	+2·1	−1·7	+2·0	−0·9	+1·7	+0·4	+2·0	−0·7	+2·4	−0·6	+1·2	−1·7	+2·0	−1·1	+1·6
1 to 2	0·0	+1·6	−0·6	0·0	−0·8	+0·1	−0·4	+0·7	−2·0	+2·9	−1·9	+3·3	−2·0	+3·0	−2·1	+2·7	−1·9	+2·8	−0·7	+2·2	+0·3	+3·0	−0·8	+2·5	−0·4	+1·3	−1·8	+2·8	−1·1	+2·1
2 to 3	0·0	+1·9	−0·5	−0·1	−0·8	+0·2	−0·7	+1·1	−2·2	+3·5	−1·5	+4·2	−2·1	+3·8	−2·1	+3·1	−1·8	+3·1	−0·6	+2·8	−0·3	+4·0	−0·8	+3·2	−0·5	+1·7	−1·8	+3·4	−1·1	+2·5
3 to 4	0·0	+2·1	−0·6	+0·2	−0·7	−0·1	−0·6	+1·2	−2·1	+4·1	−0·7	+5·0	−1·4	+4·5	−1·9	+3·7	−1·5	+3·5	−0·6	+4·2	−1·0	+5·2	−0·6	+3·7	−0·6	+2·1	−1·4	+4·1	−1·0	+3·1
4 to 5	+0·4	+2·2	0·0	−0·2	−0·4	+0·6	−1·0	+2·1	−1·8	+4·3	−0·4	+5·6	−1·0	+5·1	−1·7	+4·4	−1·4	+4·3	−0·9	+5·2	−1·5	+6·2	−0·6	+4·4	−0·5	+2·5	−1·3	+4·8	−0·9	+3·6
5 to 6	+0·4	+3·0	+0·7	0·0	−0·3	+0·5	−1·3	+3·0	−1·9	+4·9	0·0	+6·1	−0·7	+5·7	−1·5	+4·7	−1·5	+4·9	−1·3	+6·7	−2·1	+7·1	−0·8	+5·0	−0·6	+3·1	−1·2	+5·4	−0·8	+4·2
6 to 7	+0·5	+3·6	+0·1	+1·1	+0·1	+1·2	−1·2	+3·6	−2·0	+5·7	−0·2	+6·6	−0·7	+6·2	−2·0	+5·6	−1·9	+5·9	−2·1	+7·8	−2·5	+7·7	−1·0	+5·4	−0·7	+3·8	−1·5	+6·3	−1·1	+5·0
7 to 8	−0·1	+3·4	−0·1	+1·2	−0·2	+1·2	−1·4	+4·2	−2·0	+6·3	−0·7	+7·6	−1·2	+6·7	−2·4	+6·3	−2·1	+7·0	−2·4	+8·2	−2·6	+8·0	−1·1	+5·5	−1·0	+3·9	−1·9	+7·0	−1·4	+5·4
8 to 9	+0·1	+3·2	+0·4	+1·0	+0·2	+1·2	−1·3	+4·3	−2·1	+6·5	−0·9	+7·2	−1·5	+7·2	−2·4	+6·7	−2·4	+7·5	−2·2	+7·7	−2·7	+6·7	−1·4	+4·4	−0·8	+3·5	−2·0	+7·1	−1·4	+5·3
9 to 10	−0·2	+2·0	+0·3	+0·5	+0·1	+1·1	−1·4	+2·6	−2·1	+5·5	−1·6	+6·5	−1·6	+6·6	−2·3	+6·2	−2·4	+7·6	−1·8	+6·0	−2·8	+3·8	−1·4	+2·2	−0·9	+2·0	−2·0	+6·4	−1·4	+4·2
10 to 11	−0·4	−0·1	0·0	−0·1	−0·2	+0·6	−1·4	+1·2	−2·6	+3·0	−2·7	+4·1	−2·4	+4·4	−2·7	+4·2	−2·7	+4·5	−1·9	+1·8	−2·2	−0·6	−0·9	−0·5	−0·9	+0·1	−2·6	+3·6	−1·7	+1·8
11 to 12	−0·2	−1·3	+0·2	−0·7	−0·1	−0·1	−0·5	−1·1	−1·9	−1·2	−2·7	+1·3	−2·4	+1·2	−2·2	+0·3	−1·7	−0·6	−0·8	−2·8	−1·2	−3·7	−0·4	−2·3	−0·4	−1·5	−2·0	−0·3	−1·2	−0·9
12 to 13	−0·4	−2·4	+0·5	−0·9	+0·2	−1·5	+0·2	−2·6	−0·2	−5·0	−2·3	−2·7	−1·6	−2·8	−0·9	−3·8	−0·7	−5·1	0·0	−6·3	0·0	−6·2	0·0	−4·5	0·0	−3·0	−1·0	−4·2	−0·4	−3·6
13 to 14	−0·1	−3·5	+0·3	−1·3	+0·3	−1·6	+0·6	−3·7	+1·1	−7·3	−1·4	−6·5	−0·8	−5·6	+0·4	−6·5	+0·5	−7·3	+1·3	−7·9	+1·4	−7·8	+0·7	−5·6	+0·5	−3·9	+0·1	−6·6	+0·4	−5·3
14 to 15	−0·1	−4·5	+0·7	−1·3	+0·3	−2·0	+1·6	−4·5	+2·7	−8·7	−0·1	−8·6	+0·4	−8·0	+1·6	−8·0	+1·7	−8·4	+2·7	−8·7	+2·2	−8·8	+1·5	−6·8	+1·0	−4·6	+1·4	−8·1	+1·3	−6·3
15 to 16	+0·4	−4·4	+0·6	−1·2	+0·8	−2·1	+2·3	−4·6	+3·5	−8·9	+1·2	−9·9	+1·5	−9·0	+2·8	−8·0	+3·2	−8·6	+3·6	−9·0	+2·9	−8·5	+1·8	−6·8	+1·4	−4·6	+2·6	−8·5	+2·0	−6·5
16 to 17	+0·5	−3·8	+0·7	−1·1	+1·1	−1·6	+2·6	−4·1	+4·5	−8·0	+2·5	−9·7	+2·6	−8·7	+4·1	−7·6	+4·3	−7·6	+4·1	−8·0	+3·7	−8·4	+2·0	−6·5	+1·7	−4·3	+3·6	−7·9	+2·7	−6·1
17 to 18	+0·3	−3·4	+0·4	−0·9	+1·1	−1·3	+2·2	−3·5	+4·5	−6·1	+3·8	−8·1	+3·7	−7·8	+4·8	−6·4	+4·7	−6·5	+3·6	−6·5	+3·2	−6·7	+1·7	−4·9	+1·4	−3·4	+4·1	−6·9	+2·8	−5·2
18 to 19	+0·7	−2·1	+0·2	−0·3	+1·1	−0·3	+1·8	−1·9	+4·2	−4·4	+4·6	−6·4	+4·7	−6·6	+5·3	−5·3	+4·9	−5·2	+3·2	−4·4	+2·6	−4·3	+1·4	−3·1	+1·3	−2·0	+4·4	−5·4	+2·9	−3·7
19 to 20	−0·1	−0·9	−0·2	+0·3	+0·8	+0·2	+1·1	−0·7	+3·3	−2·2	+4·3	−5·2	+4·8	−5·6	+5·1	−4·6	+4·4	−3·9	+2·1	−2·5	+1·1	−1·6	+1·2	−1·1	+0·6	−0·6	+3·9	−4·0	+2·3	−2·3
20 to 21	−0·1	−0·1	−0·1	+0·5	+0·4	+0·8	+0·7	+0·1	+1·7	−0·9	+2·7	−3·2	+3·4	−3·5	+3·3	−2·4	+2·7	−2·4	+0·5	−0·8	+0·5	+0·2	+0·3	+0·2	+0·2	+0·3	+2·3	−2·2	+1·3	−1·0
21 to 22	−0·3	+0·5	−0·2	+0·5	−0·1	+1·1	+0·2	+0·5	+0·7	+0·3	+1·1	−1·1	+1·5	−1·2	+0·9	−0·4	+0·5	0·0	−1·0	+0·6	+0·4	+0·7	+0·2	+0·8	0·0	+0·7	+0·6	−0·3	+0·3	+0·2
22 to 23	−0·1	+1·0	−0·7	+0·4	−0·4	+1·1	−0·1	+0·7	−0·1	+1·3	−0·4	+0·1	+0·2	+0·1	−0·3	+0·9	−0·8	+1·4	−1·4	+1·2	+0·3	+1·0	−0·3	+1·1	−0·2	+0·9	−0·5	+0·8	−0·3	+0·8
23 o 24	−0·2	+1·4	−0·6	+0·8	−0·6	+1·1	−0·3	+0·7	−1·2	+1·9	−1·4	+1·3	−1·1	+1·3	−1·2	+1·6	−1·4	+1·8	−1·4	+1·3	+0·1	+1·5	−0·6	+2·0	−0·4	+1·3	−1·3	+1·5	−0·8	+1·4

137. The numbers in Table 77 have been curved for the north and east components separately. in the same manner as for the other elements hitherto dealt with, forming figs. 69 to 98.

The north and east components (of Table 76) have also been curved conjointly in the manner described in paragraph 131, forming figs. 99 to 110, but on the form of these curves, as well as of fig. 10, thin circular arcs are described from the zero point at intervals of one mile, and thicker arcs for every fifth mile; also radial direction lines are marked for every needful point of the compass. Having plotted the several points, and marked them with the respective hours of the day, the points of every two successive hours are joined by straight lines (in black ink), and we thus obtain curves which completely represent the normal winds of the several months. Lines drawn from each hourly point to the zero of the form represent, both in direction and by their lengths in velocity, the resultant wind of that hour; and the lines joining the successive hourly points, estimated in the same manner, represent the accessions of wind gained in the several hourly intervals. The lengths and directions are easily read off by means of the circular arcs and radial lines marked in the forms. A point surrounded by a small circle, and joined to the zero point by a black line, is marked on each month's figure to show the normal wind of the month. The lines drawn in blue ink from the zero point of some of the curves represent the direction of the coast line to northward of Bombay.

The curves both of north and east components show a characteristic diurnal variation, which is large in the dry months of the year, and almost vanishes in the course of the monsoon; retaining, notwithstanding, in all months a definite character. The changes of character of the diurnal variation of the two elements in the course of the year, although closely related, are not, it will be shown later, in all respects the same. The diurnal range of the north component is, on the average, rather less than half that of the east component, though in some months it is very much less, and in others reaches, or even surpasses, the half. The most prominent feature in the north component curves, from September to May, is the great elevation, implying excess of north wind, at hours varying from 16·5 to 19, with an approximately symmetrical descent, during October to February, for the preceding and following six or eight hours; towards the middle of the remaining hours there is either a small rise as in November to March, or a tendency towards one as in September, October, April, and May. From June to August the range is very small, and the double oscillation which exists, as a secondary feature, in the remaining curves has acquired a relative prominence. In the east component curves the most prominent feature is a great depression, implying defect of east or excess of west wind, at about 15 hours; from October to June there is only one oscillation in the day, with a maximum at hours varying from 6·5 to 9; but there are inflexions in all the curves, indicative of the presence of a variation which runs through its course twice in the 24 hours; and in the curves of the months July to September it exhibits itself distinctly as a double oscillation, showing two maxima and two minima in the course of the day. In November the range of the variation of the east component of the wind is seven times as great as in July.

138. The curves (figs. 99 to 110) of resultant winds at each hour of the typical day of each month show also the diurnal variations for the typical days, if the directions and velocities of the hourly inequalities be reckoned from the centre of gravity of the

24 hourly points, that is, from the point enclosed by a small circle, instead of being reckoned from the zero point. As a good example of the general type of the curves of diurnal variation of the resultant wind, and as the boldest of all, we may select the curve for November for description in detail, and afterwards refer to the peculiarities only of the other months' curves. We first note the regular sweep along an arc with its convex side downward, from right to left, between the hours $7\frac{1}{2}$ and $15\frac{1}{2}$, with greatest rapidity of change at the middle hours, an intermediate rate at the later hours, and the least rate at first, and with a total change of velocity of the east component of $17\frac{1}{2}$ miles per hour. The return movement which follows is accompanied, until $18\frac{1}{2}$ hours, by an upward deflection, and afterwards by a gradual depression till $0\frac{1}{2}$ hours, thus forming the great loop which represents the principal movement of the day. The return movement eastward, nearly three-fourths of which has been accomplished at $0\frac{1}{2}$ hours, is most rapid about $20\frac{1}{2}$ hours; as it continues a gradual elevation till $5\frac{1}{2}$ hours, followed by a small depression till $7\frac{1}{2}$ hours, brings back the conditions with which we commenced the day. The double oscillation of the north component is strongly marked, whilst the east component has but a single march to and fro in the course of the day. In December, January, and February the size of the enclosures formed by the curves is generally smaller than in November, showing a smaller amplitude of variation, and the night depression and eastward movement reach their extremes later. In March the smaller night loop has encroached upon the larger loop, becoming thereby considerably elongated; the hours at which the extreme right and left points are attained are the same as in November, viz., $7\frac{1}{2}$ and $15\frac{1}{2}$, but the hours of the maximum elevation and of greatest night depression are earlier, being $16\frac{1}{2}$ and 23 respectively. The curve of April differs from that of March, chiefly in the much smaller extent of the night depression. In May the figure is much reduced in size, and the night depression occurs later by two hours or more than in April, thus again reducing the extent of the smaller loop relatively to the larger. In June the figure is further reduced in size, and has acquired a nearly horizontal position, but the double oscillation of the north component is distinctly discernible. In July the figure is reduced to a minimum, and no longer retains its typical form, but the most prominent features of the type curve, viz., that the hours from $13\frac{1}{2}$ to $16\frac{1}{2}$, and generally the afternoon hours, lie to the left of the extremity of the monthly normal, whilst the hours $6\frac{1}{2}$ to $8\frac{1}{2}$ lie to the right of it, is still present; and the night depression, which is lowest at $0\frac{1}{2}$ hour, has become looped and a principal feature, projecting considerably below the rest of the figure. The typical day of this month is the first on which the double oscillation of the east component appears, and the only other which exhibits it is that of the succeeding month, August The principal change from July to August is that the great loop reappears in systematic form, though diminutive in size. In September the typical form of the curve has been recovered, but it is still small; in October it is much enlarged, but in both months the increase of the north component after the night depression is very trifling. The rotund form of the great loop is maintained from October to February, and partially in March, but in April, May, and September it has a somewhat narrow and elongated form. The diurnal inequality passes through the direction south, latest in November and December, viz., at a few minutes before noon; in September and October this occurs at about 11 hours and $11\frac{1}{4}$ hours respectively; in April and May at about $10\frac{1}{4}$ hours, and from November to March gradually earlier and earlier; in June it is about $10\frac{1}{2}$ hours; and the conversion of the mean times of occurrence of this

phenomenon into apparent times would only exaggerate the differences. Though the phenomena of land and sea breezes are masked during the months July and August by permanent strong winds from west-south-west, we see from what has been said of the curves of those months that an equivalent variation of the wind is still traceable. It is so also, after a proper separation of the normal wind of the season, in every part of the year.

139. *Bessel's coefficients.*—With the numbers in Table 77 have also been calculated the constants, amplitudes, and angles, which are inserted in the following expressions for the diurnal variations of the north and east components of the wind, in which θ represents the hour of the day reckoned from 30 minutes after midnight, and converted into arc at the rate of 15° per hour.

TABLE 78.

DIURNAL VARIATION of NORTH COMPONENT of WIND.

January	$\Delta N = 3{\cdot}36 \sin(\theta + 185^\circ\ 49') + 1{\cdot}67 \sin(2\theta + 290^\circ\ 17') + {\cdot}27 \sin(3\theta + 345^\circ\ 18') + {\cdot}21 \sin(4\theta + 45^\circ\ 0') + \&c.$
February	$\Delta N = 3{\cdot}14 \sin(\theta + 188\ 59) + 1{\cdot}68 \sin(2\theta + 300\ 5) + {\cdot}27 \sin(3\theta + 344\ 56) + {\cdot}17 \sin(4\theta + 45\ 0) + \&c.$
March	$\Delta N = 2{\cdot}38 \sin(\theta + 199\ 26) + 1{\cdot}55 \sin(2\theta + 339\ 34) + {\cdot}35 \sin(3\theta + 32\ 21) + {\cdot}05 \sin(4\theta + 0\ 0) + \&c.$
April	$\Delta N = 2{\cdot}43 \sin(\theta + 182\ 35) + 1{\cdot}17 \sin(2\theta + 4\ 53) + {\cdot}35 \sin(3\theta + 93\ 16) + {\cdot}09 \sin(4\theta + 108\ 26) + \&c.$
May	$\Delta N = 1{\cdot}34 \sin(\theta + 197\ 46) + {\cdot}65 \sin(2\theta + 334\ 37) + {\cdot}07 \sin(3\theta + 195\ 57) + {\cdot}04 \sin(4\theta + 206\ 34) + \&c.$
June	$\Delta N = {\cdot}02 \sin(\theta + 180\ 0) + {\cdot}37 \sin(2\theta + 306\ 15) + {\cdot}05 \sin(3\theta + 165\ 58) + {\cdot}09 \sin(4\theta + 159\ 27) + \&c.$
July	$\Delta N = {\cdot}54 \sin(\theta + 264\ 43) + {\cdot}28 \sin(2\theta + 302\ 0) + {\cdot}11 \sin(3\theta + 197\ 38) + {\cdot}07 \sin(4\theta + 213\ 41) + \&c.$
August	$\Delta N = {\cdot}72 \sin(\theta + 222\ 45) + {\cdot}45 \sin(2\theta + 275\ 5) + {\cdot}06 \sin(3\theta + 45\ 0) + {\cdot}02 \sin(4\theta + 90\ 0) + \&c.$
September	$\Delta N = 1{\cdot}63 \sin(\theta + 193\ 31) + {\cdot}70 \sin(2\theta + 340\ 1) + {\cdot}15 \sin(3\theta + 101\ 19) + {\cdot}05 \sin(4\theta + 270\ 0) + \&c.$
October	$\Delta N = 3{\cdot}17 \sin(\theta + 194\ 15) + 1{\cdot}37 \sin(2\theta + 307\ 17) + {\cdot}22 \sin(3\theta + 125\ 50) + {\cdot}07 \sin(4\theta + 15\ 57) + \&c.$
November	$\Delta N = 2{\cdot}06 \sin(\theta + 173\ 1) + 2{\cdot}17 \sin(2\theta + 276\ 36) + {\cdot}25 \sin(3\theta + 334\ 26) + {\cdot}13 \sin(4\theta + 13\ 0) + \&c.$
December	$\Delta N = 2{\cdot}52 \sin(\theta + 177\ 30) + 1{\cdot}85 \sin(2\theta + 270\ 56) + {\cdot}26 \sin(3\theta + 302\ 28) + {\cdot}17 \sin(4\theta + 30\ 58) + \&c.$
April to September	$\Delta N = 1{\cdot}03 \sin(\theta + 198\ 5) + {\cdot}52 \sin(2\theta + 333\ 55) + {\cdot}09 \sin(3\theta + 108\ 26) + {\cdot}03 \sin(4\theta + 180\ 0) + \&c.$
October to March	$\Delta N = 2{\cdot}74 \sin(\theta + 187\ 7) + 1{\cdot}58 \sin(2\theta + 294\ 37) + {\cdot}18 \sin(3\theta + 353\ 39) + {\cdot}13 \sin(4\theta + 32\ 28) + \&c.$
Year	$\Delta N = 1{\cdot}88 \sin(\theta + 190\ 7) + 1{\cdot}02 \sin(2\theta + 304\ 10) + {\cdot}08 \sin(3\theta + 23\ 12) + {\cdot}06 \sin(4\theta + 45\ 0) + \&c.$

TABLE 79.

DIURNAL VARIATION of EAST COMPONENT of WIND.

January	$\Delta E = 6{\cdot}48 \sin(\theta + 20^\circ\ 59') + 2{\cdot}50 \sin(2\theta + 187^\circ\ 48') + {\cdot}78 \sin(3\theta + 46^\circ\ 3') + {\cdot}51 \sin(4\theta + 226^\circ\ 35') + \&c.$
February	$\Delta E = 6{\cdot}73 \sin(\theta + 22\ 20) + 3{\cdot}00 \sin(2\theta + 193\ 43) + 1{\cdot}05 \sin(3\theta + 55\ 51) + {\cdot}64 \sin(4\theta + 245\ 2) + \&c.$
March	$\Delta E = 7{\cdot}06 \sin(\theta + 27\ 57) + 3{\cdot}30 \sin(2\theta + 215\ 8) + {\cdot}50 \sin(3\theta + 86\ 34) + {\cdot}38 \sin(4\theta + 293\ 12) + \&c.$
April	$\Delta E = 7{\cdot}22 \sin(\theta + 34\ 10) + 2{\cdot}86 \sin(2\theta + 224\ 35) + {\cdot}15 \sin(3\theta + 148\ 24) + {\cdot}56 \sin(4\theta + 340\ 17) + \&c.$
May	$\Delta E = 5{\cdot}39 \sin(\theta + 37\ 46) + 1{\cdot}97 \sin(2\theta + 216\ 21) + {\cdot}06 \sin(3\theta + 161\ 34) + {\cdot}30 \sin(4\theta + 17\ 14) + \&c.$
June	$\Delta E = 3{\cdot}37 \sin(\theta + 35\ 20) + 1{\cdot}35 \sin(2\theta + 206\ 57) + {\cdot}15 \sin(3\theta + 109\ 39) + {\cdot}16 \sin(4\theta + 18\ 26) + \&c.$
July	$\Delta E = {\cdot}74 \sin(\theta + 50\ 30) + {\cdot}71 \sin(2\theta + 203\ 18) + {\cdot}19 \sin(3\theta + 117\ 54) + {\cdot}16 \sin(4\theta + 18\ 26) + \&c.$
August	$\Delta E = 1{\cdot}08 \sin(\theta + 46\ 52) + 1{\cdot}07 \sin(2\theta + 196\ 14) + {\cdot}01 \sin(3\theta + 90\ 0) + {\cdot}08 \sin(4\theta + 225\ 0) + \&c.$
September	$\Delta E = 3{\cdot}24 \sin(\theta + 26\ 43) + 1{\cdot}91 \sin(2\theta + 209\ 31) + {\cdot}14 \sin(3\theta + 90\ 0) + {\cdot}19 \sin(4\theta + 341\ 34) + \&c.$
October	$\Delta E = 6{\cdot}45 \sin(\theta + 29\ 2) + 2{\cdot}83 \sin(2\theta + 199\ 35) + {\cdot}75 \sin(3\theta + 27\ 56) + {\cdot}30 \sin(4\theta + 270\ 0) + \&c.$
November	$\Delta E = 7{\cdot}76 \sin(\theta + 18\ 47) + 2{\cdot}49 \sin(2\theta + 182\ 59) + {\cdot}63 \sin(3\theta + 5\ 26) + {\cdot}15 \sin(4\theta + 203\ 12) + \&c.$
December	$\Delta E = 7{\cdot}34 \sin(\theta + 16\ 57) + 2{\cdot}33 \sin(2\theta + 178\ 46) + {\cdot}57 \sin(3\theta + 27\ 1) + {\cdot}33 \sin(4\theta + 223\ 47) + \&c.$
April to September	$\Delta E = 3{\cdot}49 \sin(\theta + 35\ 20) + 1{\cdot}62 \sin(2\theta + 212\ 54) + {\cdot}10 \sin(3\theta + 119\ 3) + {\cdot}21 \sin(4\theta + 354\ 34) + \&c.$
October to March	$\Delta E = 6{\cdot}95 \sin(\theta + 22\ 30) + 2{\cdot}68 \sin(2\theta + 194\ 15) + {\cdot}65 \sin(3\theta + 41\ 16) + {\cdot}34 \sin(4\theta + 245\ 42) + \&c.$
Year	$\Delta E = 5{\cdot}20 \sin(\theta + 26\ 46) + 2{\cdot}12 \sin(2\theta + 201\ 15) + {\cdot}34 \sin(3\theta + 49\ 46) + {\cdot}17 \sin(4\theta + 280\ 0) + \&c.$

140. Observing that in both the Tables 78 and 79 the coefficients of the first and second terms are much more considerable than those of the third and fourth terms, we may now obtain very approximate graphical representations of the resultant wind variations in forms of much greater simplicity than those of the figures 99 to 110. For, neglecting the

third and fourth terms, and combining the first term of Table 78 with the first term of Table 79 for the respective months, and thus calculating the subordinate inequality for each hour of the day, and plotting the resultant inequality in the manner that has been described in paragraph 131, we obtain a series of 12 ellipses, one for each month, the *radii vectores* of which represent in direction and velocity the inequalities of the subordinate variation which has *one day* as its period. Similarly by combining the second term of Table 78 with the second term of Table 79 we obtain 12 other ellipses, which represent the inequalities of the subordinate variation which has half a day for its period; and the combination of the two inequalities for a given hour of a given month, taken from the corresponding pair of ellipses, yields a resultant inequality which is nearly the same as the actual one. But these constructions will be found most convenient in studying the changes, from month to month, in the simple subordinate variations of single periods, that is, in considering the first-term ellipses by themselves, and the second-term ellipses by themselves. They form the figures 118 to 143 of Plate XX. The first-term ellipses represent what may be regarded as the immediate effects of the land and sea breeze theory (to be referred to again later), and they show how nearly these effects constitute a simple to-and-fro movement of the air along a fixed direction line, deviating little from W.N.W. and E.S.E.; they show also the extent of departure, in the course of the year, from these simple conditions. The phenomena represented by the second-term ellipses, or the same phenomena with some admixture, and exhibited in a different way, have led to an interesting theoretical speculation by Mr. F. Chambers, of the Colába Observatory, on the subject of a general connection between the diurnal variations of the wind and barometric pressure. The considerations which gave rise to this speculation are set forth in a paper entitled "The Diurnal Variations of the Wind and Barometric Pressure at Bombay," which had the honour to find a place in the "Philosophical Transactions" of the Royal Society.*

141. *Track of the air on typical days.*—To the meteorologist the chief significance of wind lies in the interchange of meteorological conditions that result from the transfer of bodies of air from districts of a certain character to others of like or different character; and the bodily motion of the atmosphere, carrying, as part of it, the vitiated air of populous towns and districts, and supplying its place by fresh air, pure or impure, according to the influences to which it has been subjected in its previous course, is the relation in which the wind affects sanitation. We have thought, therefore, that it would be interesting both to the meteorologist and to the sanitary officer to give even an approximate idea that can be readily acquired of the course pursued by the air in the 24 hours preceding its arrival at Bombay; and this not only on account of the interest and importance of the particular case, but as an example which might with some advantage be generally followed. We make the supposition—which is doubtless only approximately true, and less so, in the case of Bombay, than it would be in a district comprising less variable physical features—that the body of air which is passing over Bombay at a given moment has during the preceding 24 hours moved always with the same velocity, and in the same direction as the contemporaneous wind blowing at Bombay. On this supposition we draw a curve for the typical day of a given month, calling it the track of an imaginary balloon, in the following manner:—Having laid down on the form a vertical line to represent the direction north and south, and a horizontal line to represent east and west, we take any point in the latter line, and mark it .0 to represent 0 hours;

* "Philosophical Transactions," vol. 163, page 1, 1873.

from this point we set off the north and east components of the normal wind at $0\frac{1}{2}$ hour in the downward and left-hand directions respectively, and mark the point 1; similarly from the point 1 we set off the north and east components of $1\frac{1}{2}$ hours, and mark the point 2; and proceeding thus till the 24 hours have been marked down, we then form a curve by joining up the successive hour-points by straight lines. Such curves have been drawn, forming figs. 111 to 117, for the typical day of each of the months October to April, these being the only months in which the normal wind blows during part of the day from landward. The scale upon which they are drawn is 15 miles to an inch. If now we place the form over a map of the district around Bombay, drawn to the same scale, with its cardinal direction lines parallel to those of the map, and set any hour-point over Colába, the preceding part of the curve traced on the map will show where the air that passes over Colába at that hour was at every preceding hour. If necessary the curve must be prolonged upward by repeating the curvature at the bottom, and making the 24 hour-point coincide with the 0 hour-point. An example of the use of these curves has already been given in the discussion of the diurnal variation of vapour pressure at Colába; and the mode of application of them to questions which affect the sanitary condition of Bombay and its neighbourhood is obvious.

142. *Small corrections of diurnal variations.*—In deducing diurnal variations from hourly observed values of any element, we ought in strictness to eliminate the progressive increase or decrease due to the change, in the 24 hours of the typical day of each month, of the annual inequality of the element, allowing a proportional part of this change for each hour. It has not, however, been deemed requisite to apply this small correction to any of the diurnal variations deduced herein, and in consequence there are sometimes small irregularities in the numbers and in the corresponding curves, which are inappreciable between successive hours, but exhibit themselves distinctly between the first and last hours of the day. These hours for all the elements, except barometric pressure, are 0 and 23; in the excepted case they are, for a part of the period of observation, 16 and 15, and for the remaining part 0 and 23. The corrections that should be applied for the first and last hours are shown for each element and each month in the following table.

TABLE 80.

Element.	Corrections required.											
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Barometric pressure at 16 hours, inch " at 15 " " " at 0 " " " at 23 " "	The only correction which exceeds ·001 inch is that for 0 hours and the month of May; its value is −·001 inch.											
Temperature of the air at 0 " " at 23 "	All the corrections are less than 0°·1.											
Pressure of vapour at 0* " inch " at 23* " "	+·002 −·002	+·002 −·002	+·002 −·002							−·002 +·002	−·001 +·001	
North component of the wind at 0 " " " at 23 " "	The corrections are all less than ·1 mile.											
East component of the wind at 0 " " " at 23 " "	The only corrections which exceed ·1 *mile* are those for 0^h (−·1) and 23^h (+·1) of June, and 0^h (+·1) and 23^h (−·1) of September.											

* For the spaces left blank the corrections are all less than ·001 inch.

143. *Variation of the north and east components of the wind with the moon's age.* —To find whether the relative positions of the sun and moon affect the observed velocities of the wind the following process was adopted:—The mean daily velocities of each component were entered in order, in tables of 30 columns and 87 lines each; the columns were numbered consecutively, to represent solar days after new moon, and the lines consecutively, to represent lunations, the number of which afforded by the seven years' observations is 87. The solar day which began within 12 hours of the occurrence of each new moon was taken as the first solar day after new moon. The means of the numbers in the several columns, the variations of which may be taken as indicating approximately the influence of the moon's age on the wind, are shown in Table 81, and are curved in figs. 234 and 235. It would have been more accurate to treat the daily abnormals, instead of the daily means, in the way described; but it comes to the same thing, and is more convenient, to treat separately the daily normals in the same way, and deduct the mean results for each solar day after new moon from those derived from the daily means. The subtraction has not been made, because the range of the results derived from the daily normals is, as might be presumed, very small. The results derived from the daily normals of the north component are, however, shown in Table 81, and curved (in red) on the same form with fig. 234. Presuming that those for the east component will probably be as little influential as those for the north component, it has not been thought worth while to work them out.

TABLE 81.

SHOWING, for each SOLAR DAY after New Moon, the MEAN VELOCITIES of the NORTH and EAST COMPONENTS of the WIND, and the MEAN VELOCITY of the NORMAL NORTH COMPONENT.

Solar Days after New Moon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
North Component	+1·29	+1·98	+2·28	+2·19	+1·94	+2·46	+3·03	+2·62	+2·56	+2·62	+2·48	+2·53	+2·01	+1·75	+2·65
Normal North Component	+2·08	+2·05	+2·07	+2·05	+2·05	+2·04	+2·08	+2·15	+2·06	+2·03	+2·12	+2·02	+2·02	+2·02	+2·13
East Component	−6·26	−5·89	−6·16	−6·07	−6·27	−6·21	−6·40	−6·05	−5·89	−6·03	−5·96	−5·71	−5·28	−5·02	−5·23

TABLE 81—*continued.*

Solar Days after New Moon	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
North Component	+2·01	+2·63	+2·80	+2·42	+1·68	+0·96	+1·43	+1·53	+1·14	+0·79	+1·63	+1·70	+2·38	+1·94	+1·53
Normal North Component	+2·13	+2·02	×2·01	+2·01	+2·02	+1·96	+2·01	+2·04	+2·02	+2·01	+2·01	+2·02	+2·01	+1·91	+2·70
East Component	−5·53	−6·43	−6·52	−6·63	−7·10	−6·84	−6·80	−6·75	−6·53	−6·19	−6·28	−6·51	−6·50	−6·58	−6·15

The discordance of the means of the thirtieth days arises from their being deduced from small numbers of daily means, nearly half the lunations having no thirtieth day. The curves, and especially the east component curve, seem to imply something more than mere arithmetical results: they have each a range of about two miles per hour of velocity, and the east component curve has a well-marked maximum about the fourteenth day, and a well-marked minimum about the twentieth day, with a fairly regular progression between and on either side of these phases. The north component curve, though more erratic, divides the lunations into halves, in one of which the ordinates are mostly in excess of the mean, and in the other in defect. The extension of this inquiry to lunar *diurnal* variations of the wind would probably indicate a connection with the tides, showing itself both in the diurnal and menstrual variations; but it cannot be undertaken for the present paper.

144. *Variability of the wind.*—In Table 82 is shown the maximum force of the wind in each of the years 1847 to 1874, expressed for the first 19 years in pounds of pressure on the square foot, and for the last nine years in miles per hour of velocity. The maxima of pressure have reference to the pressure at any moment, to mean daily pressures, and to mean monthly pressures; the maxima of velocity refer to hourly, daily, and monthly means.

TABLE 82.

SHOWING the MAXIMUM FORCE of the WIND observed in each of the Years 1847 to 1874.

Year.	Absolute Maximum Pressure.	Time of Occurrence.			Maximum Mean Daily Pressure.	Date of Occurrence.		Maximum Mean Monthly Pressure.	Month of Occurrence.
	Lbs.	Hour.	Day.	Month.	Lbs.	Day.	Month.	Lbs.	
1847	3·60	15	24	6	1·63	25	5	0·65	4
1848	5·26	22	8	10	3·21	18	5	0·68	7
1849	9·00	17	29	7	2·31	31	7	0·64	6
1850	15 00	17	1	11	1·60	22	7	0·37	7
1851	8·00	20	25	8	3·00	28	5	0·49	7
1852	10·70	7	11	8	1·00	21	10	0·39	6
1853	7·00	9	20	6	1·40	11	7	0·51	7
1854	35·00	4	2	11	8·06	2	11	0·33	7
1855	13·00	2	11	6	2·05	12	6	0·52	6
1856	16·00	18	21	5	3·08	30	5	0·37	5
1857	9·50	12	26	6	1·29	18	6	0·51	8
1858	12·00	17	24	6	2·38	15	7	0·55	7
1859	11·25	22	10	7	4·29	22	7	1·02	7
1860	14·00	7	16	10	2·01	3	8	0·48	7
1861	8·75	1	3	6	2·26	2	7	0·71	7
1862	10·75	21	14	6	4·02	14	6	0·67	6
1863	7·75	12	9	6	3·05	9	6	0·92	6
1864	6·25	1	14	7	1·25	22	7	0·62	7
1865	10·50	17	26	8	1·95	8	6	0·51	6
	Maximum Hourly Mean Velocity.	Time of Occurrence.			Maximum Mean Daily Velocity.	Date of Occurrence.		Maximum Mean Monthly Velocity.	Month of Occurrence.
	Miles.	Hour.	Day.	Month.	Miles.	Day.	Month.	Miles.	
1866	58·7	18	3.	8	46·2	14	6	22·5	6
1867	41·0	10	18	7	32·1	19	7	19·4	7
1868	50·0	16	9	8	39·5	9	8	19·9	6
1869	59·0	18	4	6	38·5	5	6	20·7	7
1870	41·0	17	3	10	31·5	28	7	19·5	7
1871	48·0	7	16	1	32·1	25	6	21·3	7
1872	46·0	12	16	6	32·3	13	7	19·8	7
1873	43·0	15	1	6	30·0	9	6	23·0	7
1874	47·0	14	19	6	36·5	19	6	19·6	6

The maximum pressure of the wind at any moment during the period 1847 to 1865 occurred during the hurricane of 1st–2nd November 1854, and exceeded 29·5 lbs., on reaching which Osler's anemometer became deranged. The maximum estimated force

was 50 lbs. The number (35·0) entered in the table was obtained from measurements with Lind's wind gauge at 4 a.m. on the 2nd November. The maximum daily mean pressure was 8·06 lbs., and occurred on the same day (2nd November). The maximum monthly mean pressure was 1·02 lbs., being that of July 1859. In the period 1866 to 1874 the maximum velocity and time of its occurrence were as follows:—

Of hourly means - - 59 miles, at 18 hours on the 4th June 1869.
Of daily means - - 46·2 miles, on the 14th June 1866.
Of monthly means - 23·0 miles, being for July 1873.

The numbers in Table 82 are represented graphically by the diagrams 204 and 205 of Plate XXIX., the red, black, and violet lines referring to the hourly, daily, and monthly means respectively.

145. Table 83 shows the maximum wind which blew in each month of the same name throughout the period from June 1867 to December 1874,—first, with respect to hourly means, and, secondly, with respect to daily means.

TABLE 83.

Month.	Individual Hours.				Daily Means.			Month.	Individual Hours.				Daily Means.		
	Maximum Velocity.	Time of Occurrence.			Maximum Velocity.	Date of Occurrence.			Maximum Velocity.	Time of Occurrence.			Maximum Velocity.	Date of Occurrence.	
	Miles.	Hr.	Day.	Year.	Miles.	Date.	Year.		Miles.	Hr.	Day.	Year.	Miles.	Date.	Year.
January -	48	7	16	1871	20·9	5	1873	July -	48	16	17	1869	34·1	17	1869
February	29	20	22	1872	20·0	6	1869	August -	50	16	9	1868	39·5	9	1868
March -	33	15	23	1873	21·3	2	1868	September	38	9	16	1872	24·6	15	1872
April -	36	16	13	1870	24·3	24	1872	October -	41	17	3	1870	22·2	21	1867
May -	36	3	18	1868	26·1	9	1874	November	48	19	12	1871	28·0	12	1871
June -	59	18	4	1869	38·5	5	1869	December	30	18	31	1870	18·2	31	1870

These numbers are figured in the diagram 206 of Plate XXIX., the red lines referring to the maxima of hourly means, and the black to those of daily means.

146. *Probable error of normal wind.*—Although the signification that we attach to the term normal wind of a certain day or hour is that it is more probable that the actual wind of that day or hour will have the velocity and direction of the normal than any other, yet in individual cases the actual wind rarely corresponds exactly with the normal, but is sometimes stronger and sometimes weaker, sometimes from the right of its direction and sometimes from the left; but, on the whole, the excesses of strength will balance the defects, and the additional winds from the right will neutralize those from the left. The actual wind may always be resolved into two equivalent component winds, one of which is the normal, and the other may be called the abnormal, and, the normal wind being supposed to be due to causes ordinarily effective, the abnormal will be due to variations in the effectiveness or power of those causes, or to extraordinary causes. If we represent the velocity of the normal north component by N, and that of the abnormal north component by Δ N, the normal east component by E, and the abnormal by Δ E, the probable error

of the north component will be $\sqrt{\frac{\Sigma(\Delta N)}{n-1}} \times \cdot 674489$, and that of the east component $\sqrt{\frac{\Sigma(\Delta E)^2}{n-1}} \times \cdot 674489$; and generally r_θ the probable error of the component in the direction θ to the east of north will be—

$$\sqrt{\frac{\Sigma\{\Delta N \cos\theta + \Delta E \sin\theta\}^2}{n-1}} \times \cdot 674489 = \sqrt{\frac{\cos^2\theta\,\Sigma(\Delta N)^2 + 2\sin\theta\cos\theta\,\Sigma(\Delta N.\Delta E) + \sin^2\theta\,\Sigma(\Delta E)^2}{n-1}} \times \cdot 674489$$

$$= \frac{0 \cdot 674489}{\sqrt{2(n-1)}} \sqrt{\left[\{\Sigma(\Delta N)^2 - \Sigma(\Delta E)^2\}^2 + 4\{\Sigma(\Delta N.\Delta E)^2\}^2\right]^{\frac{1}{2}} \cos\left\{2\theta - \tan^{-1}\frac{2\Sigma(\Delta N.\Delta E)}{\Sigma(\Delta N)^2 - \Sigma(\Delta E)^2}\right\} + \Sigma(\Delta N)^2 + \Sigma(\Delta E)^2}.$$

Now as r^2 is essentially positive, this expression has real values for all values of θ. The first term of the factor under the radix is a simple periodical function, going through all its phases, whilst θ passes through 180°; and the whole expression has maximum and minimum values for values of θ differing by 90°, and from its maximum value it decreases continuously, whilst θ increases by 90°, and increases continuously through the next 90°; and the curve whose radii vectors will represent the values of r_θ for all values of θ will be symmetrical in form, about two axes at right angles to each other, these being the greatest and least diameters of the figure. In constructing such figures, we need therefore only lay down the maximum and minimum axes, and complete the outline with a free hand, the axes being placed in the positions corresponding to the two values of θ given by the equation—

$$\theta = \tfrac{1}{2}\tan^{-1}\frac{2\Sigma(\Delta N.\Delta E)}{\Sigma(\Delta N)^2 - \Sigma(\Delta E)^2}.$$

147. Daily abnormals of the north and east components of the wind have been calculated for every day of the seven years June 1867 to May 1874, but using always daily normals, derived—in the same manner as has been described above—from the observations of the first four years only. These being arranged in fortnightly groups, each of which comprises the abnormals of the fortnights at the same season of all the years, the values of ΔN, ΔE, $(\Delta N)^2$, $(\Delta E)^2$, $(\Delta N.\Delta E)$, and of $\Sigma(\Delta N)^2$, $\Sigma(\Delta E)^2$, and $\Sigma(\Delta N.\Delta E)$ were calculated for each group; from these were deduced the values of $\frac{1}{2}\tan^{-1}\frac{2\Sigma(\Delta N.\Delta E)}{\Sigma(\Delta N)^2-\Sigma(\Delta E)^2}$, and, by means of the expression for r_θ, the values of the maximum and minimum probable errors in each fortnight, and with the latter have been constructed the figures 210 to 233, showing the probable sphere of abnormal variation of the wind on the typical day of each fortnight. A black line is drawn from the zero point of each fortnight to represent the normal wind of the typical day of that fortnight, and about its extremity, as a centre, is described the closed figure representing the probable errors of components of the wind of every direction. The interpretation to be put upon these figures is that on the respective typical days more than half the winds that blow would be represented by points placed within the figures; and the same closed figure of each fortnight may be applied, with the same significance, at the extremity of a line representing the normal wind of any day in the fortnight.

The values of n and the calculated values of $\Sigma(\Delta N)^2$, $\Sigma(\Delta E)^2$, $\Sigma(\Delta N.\Delta E)$, of the maximum and minimum r_θ, and of the angle $\frac{1}{2}\tan^{-1}\frac{2\Sigma(\Delta N.\Delta E)}{\Sigma(\Delta N)^2-\Sigma(\Delta E)^2}$, corresponding to the maximum r_θ, are shown in the following table, as are also the north and east components of the normal wind for each fortnight of the year.

TABLE 84.

Month	June.		July.		August.		September.		October.		November.	
Fortnight	1	2	1	2	1	2	1	2	1	2	1	2
$\Sigma(\Delta N)^2$	8864·80	1769·31	2432·94	2588·01	2883·77	2927·40	2908·13	3252·58	2080·06	1900·38	1525·99	769·21
$\Sigma(\Delta E)^2$	6646·09	6534·68	5068·76	3510·39	5852·93	1967·34	2642·68	2890·31	1038·26	475·96	851·05	630·90
$\Delta N . \Delta E)$	−4232·38	−153·55	+234·15	+853·44	+1635·65	+432·10	+175·92	−62·57	−63·31	−254·69	−493·11	+157·15
$\frac{1}{2}\tan^{-1}\frac{2\Sigma(\Delta N . \Delta E)}{\Sigma(\Delta N)^2-\Sigma(\Delta E)^2}$	142° 20′	91° 50′	84° 57′	59° 11′	66° 21′	21° 0′	26° 30′	170° 29′	176° 33′	170° 10′	152° 10′	33° 7′
n	102	103	105	112	105	112	105	104	105	112	105	105
r_θ Maximum	7·4	5·4	4·7	4·1	5·4	3·6	3·6	3·8	3·0	2·8	2·8	1·9
r_θ Minimum	3·9	2·8	3·3	2·9	3·0	2·7	3·3	3·6	2·1	1·3	1·6	1·5
North component	−5·4	−7·1	−6·4	−6·1	−4·7	−2·2	−0·7	+0·7	+3·4	+4·7	+5·1	+5·4
East component	−8·0	−12·6	−16·1	−18·0	−16·8	−13·7	−9·7	−5·8	−2·5	−0·3	+0·8	+1·3

TABLE 84—*continued.*

Month	December.		January.		February.		March.		April.		May.	
Fortnight	1	2	1	2	1	2	1	2	1	2	1	2
$\Sigma(\Delta N)^2$	651·24	1306·34	1635·68	1885·20	1621·57	1102·78	2089·55	3693·51	3704·43	3281·18	4083·04	3080·71
$\Sigma(\Delta E)^2$	453·51	563·04	570·98	726·99	443·30	509·69	469·64	386·55	315·31	358·57	542·06	598·05
$\Sigma(\Delta N . \Delta E)$	+80·38	−350·73	−616·10	−604·36	−264·09	−349·71	−656·20	−756·89	−729·29	−727·26	−907·60	−637·41
$\frac{1}{2}\tan^{-1}\frac{2\Sigma(\Delta N . \Delta E)}{\Sigma(\Delta N)^2-\Sigma(\Delta E)^2}$	19° 39′	158° 19′	155° 25′	156° 53′	167° 56′	155° 8′	160° 29′	167° 42′	168° 21′	166° 46′	166° 25′	166° 25′
n	102	110	104	111	97	100	104	111	104	104	104	108
r_θ Maximum	1·7	2·5	2·9	3·0	2·8	2·4	3·2	4·0	4·1	3·9	4·4	3·7
r_θ Minimum	1·4	1·3	1·1	1·4	1·4	1·3	1·0	1·0	0·9	0·9	1·2	1·4
North component	+5·6	+6·6	+7·7	+7·5	+7·4	+7·3	+6·9	+5·8	+4·8	+3·6	+1·5	−1·3
East component	+0·8	−0·5	−1·4	−1·8	−2·6	−3·5	−4·6	−5·6	−6·3	−6·9	−7·7	−7·2

148. On viewing the figures 210 to 233, it is impossible not to be struck by the persistency of direction of the maximum axes of the ovals of October to May, but excepting those for the last fortnight of November and first of December, and this notwithstanding the fact that the direction of the normal wind changes in the same period more than 90°. We conclude therefore that the direction of the normal does not determine, as might be surmised, and as some of the figures seem to suggest, the direction of greatest variability. The axes referred to have a direction nearly parallel to the coast line, as though abnormal winds in that direction met with less resistance than such as tend more or less directly to landward; or it may be that the currents of the ocean, which near the coast run parallel to it, create, by friction on the air, corresponding winds in addition to those which are due to other local conditions, and to the general distribution of temperature and atmospheric pressure. The smallness of the sphere of variation between the middle of November and middle of December, when the winds blow more exclusively from landward than at any other season, lends weight to the former supposition, the greater friction in passing over the land than over the sea producing a relative diminution of the abnormal wind. The resistance of the line of steep ascents to the Western Ghauts, also on the whole in the direction of greatest variability, would likewise be a reason why abnormal winds moving along the narrow strip of low land intervening between them

and the sea, should be less obstructed than such as move athwart the coast. As we have found before, the direction of greatest variability in the first half of June and last of September are in the quadrants N.W. and S.E., being due to the thunder-storms that open and close the monsoon; but the abnormal winds, like the thunder-storms, are more moderate at the end than at the beginning of the monsoon. In the second half of June the direction of principal variability is due west, and from 1st July to 15th August it deviates little from the direction of the normal wind. The great excess of variability in the monsoon months, June to September, as compared with the rest of the year is worthy of notice; as is also the fact that at no part of the year is the probable variability of direction of the normal daily wind so much as 90°. For proof of this we have only to draw pairs of tangents to the closed figures from the extremities of the fortnightly normals, when we shall find that they all include a less angle than 90°.

149. In Table 85 is shown the mean velocity of the wind, without regard to its direction, in each month of the seven years from June 1867 to May 1874; and in Table 86 is shown the mean velocity of the wind, without regard to direction, at each hour in each month and in the whole year.

TABLE 85.

Years.	June.	July.	August.	Sept.	October.	Nov.	Dec.	January.	Feb.	March.	April.	May.	Annual Means.	Years.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	
1867	15·7	19·4	18·3	12·7	9·8	11·4	9·0	10·8	10·4	12·1	12·7	10·0	12·7	1868
1868	19·9	17·9	18·8	10·7	8·4	9·1	9·7	9·2	11·5	10·8	11·3	10·7	12·3	1869
1869	17·4	20·7	13·7	14·0	9·8	10·0	9·4	10·7	9·8	11·8	10·4	9·6	12·3	1870
1870	15·2	19·5	16·8	10·7	8·8	8·7	9·2	10·0	9·8	10·2	9·6	13·2	11·8	1871
1871	18·8	21·3	19·1	11·4	8·6	10·1	9·2	11·5	11·2	11·8	12·0	10·5	13·0	1872
1872	15·2	19·8	16·4	10·5	9·4	10·0	8·2	10·8	10·3	10·2	10·1	11·8	11·9	1873
1873	17·2	23·0	17·4	11·7	8·8	9·3	9·9	11·0	10·7	11·5	11·2	11·1	12·7	1874
Means	17·1	20·2	17·2	11·7	9·1	9·8	9·2	10·6	10·5	11·2	11·0	11·0	12·4	

TABLE 86.

Hours.	June.	July.	August.	Sept.	October.	Nov.	Dec.	January.	Feb.	March.	April.	May.	Year.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
0 to 1	17·0	20·1	17·1	10·5	7·1	7·0	6·4	7·3	7·3	8·6	9·0	9·5	10·6
1 to 2	16·4	20·6	17·1	10·8	7·0	7·6	6·7	7·3	7·3	8·5	8·8	9·2	10·6
2 to 3	16·6	20·6	17·2	10·7	7·1	8·6	7·0	7·5	7·4	8·4	7·5	8·8	10 6
3 to 4	16·4	20·7	17·6	10·7	7·3	9·3	7·8	8·1	7·9	8·2	7·1	8·3	10·8
4 to 5	15·7	20·5	17·1	10·9	7·3	9·9	8·6	8·5	8·2	8·2	6·5	7·6	10·7
5 to 6	15·5	20·2	17·1	10·8	7·2	10·5	9·0	8·7	8·1	8·0	6·6	7·2	10·7
6 to 7	15·5	19·7	16·4	10·6	7·5	10·7	9·3	8·9	8·0	7·8	6·3	7·0	10·6
7 to 8	15·8	19·7	16·8	10·9	7·8	11·3	9·4	8·9	8·2	7·9	7·0	7·7	10·9
8 to 9	15·6	19·7	16·8	10·8	7·9	10·9	9·6	9·0	8·3	8·3	7·6	8·3	11·1
9 to 10	16·1	19·9	16·7	11·4	7·5	10·1	8·9	9·1	8·4	8·7	8·5	9·5	11·2
10 to 11	16·6	20·1	16·9	11·2	6·8	8·0	7·8	8·2	7·9	9·3	10·4	11·0	11·1
11 to 12	17·0	20·5	17·4	12·3	7·6	7·1	6·5	8·3	9·1	11·7	12·6	12·3	11·9
12 to 13	18·1	20·7	18·2	13·1	10·0	8·1	7·8	10·9	11·6	14·4	15·1	14·1	13·5
13 to 14	18·8	21·1	18·5	13·9	12·1	9·7	9·3	12·8	13·7	16·3	16·9	15·3	14·9
14 to 15	19·7	20·9	19·0	14·5	13·7	11·4	11·4	14·6	15·4	17·8	18·0	16·3	16·1
15 to 16	19·6	20·8	19·0	14·5	14·5	12·7	12·6	15·8	16·7	18·3	18·2	16·4	16·6
16 to 17	18·9	20·7	18·5	14·2	14·1	13·1	12·9	16·3	16·8	17·8	18·0	16·1	16·4
17 to 18	18·6	20·5	18·0	13·4	13·3	12·7	13·1	16·0	16·1	16·2	16·3	14·7	15·7
18 to 19	17·6	19·9	17·1	12·1	11·8	12·6	13·0	15·4	15·4	14·3	14·2	13·1	14·7
19 to 20	17·3	19·6	16·5	11·4	10·7	11·8	12·5	14·8	14·2	12·4	11·7	11·3	13·7
20 to 21	17·0	19·6	16·0	10·9	8·8	9·8	10·5	12·4	12·0	10·6	10·2	10·6	12·4
21 to 22	16·8	19·8	16·1	10·6	7·2	8·2	8·3	9·6	9·5	9·4	9·8	10·2	11·3
22 to 23	16·4	19·7	16·2	10·1	7·0	7·2	7·2	8·3	8·1	8·9	10·0	9·8	10·7
23 to 24	16·3	19·4	16·1	10·2	6·6	6·8	6·5	7·5	7·4	8·7	9·3	9·4	10·3

Comparison of Diurnal Variations of different Phenomena.

150. In the course of our examination of the annual variations of the several meteorological elements we have remarked upon any features possessed in common by the variations of more than one element, and especially where the relationship existing seemed to be one of cause and effect, or pointed to subjection to a common cause. But in dealing with the diurnal variations, except those of pressure of vapour, we have confined ourselves generally to the individual phenomenon under consideration. We proceed now to show that the diurnal variations of the wind, of temperature of the air, and of barometric pressure possess points, both of resemblance and of difference, of an interesting and instructive character.

The curves of temperature (figs. 39 to 53) exhibit, when inverted, striking resemblances to those of the east component of the wind (figs. 84 to 98) in all months except July and August; and even in those months the principal inflexions of the temperature curves have counterparts in those of the east component. There are, at the same time, in the wind curves, minor movements of a distinct character that do not appear in the temperature curves; and these, as well as the relations of the diurnal variations generally, can be better displayed by an appropriate consideration of the coefficients of Bessel's formula expressing the variations. These coefficients with corresponding angles we have already given for each term of the form $r_n \sin(n\theta + \alpha_n)$ in Tables 7, 25, 78, and 79, and we now give their equivalents, which have been calculated in each case for four pairs of terms of the form $(a_n \cos n\theta + b_n \sin n\theta)$.

Table 87.

Showing the Values of the Coefficients of the expression $\Delta X = a_1 \cos\theta + b_1 \sin\theta + a_2 \cos 2\theta + b_2 \sin 2\theta + a_3 \cos 3\theta + b_3 \sin 3\theta + a_4 \cos 4\theta + b_4 \sin 4\theta$ for the diurnal inequalities of each of the elements, north component of the wind, east component of the wind, temperature of the air, and barometric pressure, for the typical days of each month of the year, of the summer and winter half years, and of the whole year.

	North Component of the Wind.								East Component of the Wind.							
Coefficients	a_1	b_1	a_2	b_2	a_3	b_3	a_4	b_4	a_1	b_1	a_2	b_2	a_3	b_3	a_4	b_4
January	−·34	−3·34	−1·57	+0·58	−·12	+·24	+·15	+·15	+2·32	+6·05	−0·34	−2·48	+·56	+·54	−·37	−·35
February	−·49	−3·10	−1·45	+0·84	−·07	+·26	+·12	+·12	+2·56	+6·23	−0·71	−2·91	+·87	+·59	−·58	−·27
March	−·79	−2·24	−0·54	+1·45	+·19	+·30	·00	+·05	+3·31	+6·24	−1·90	−2·70	+·50	+·03	−·35	+·15
April	−·11	−2·43	+0·10	+1·17	+·35	−·02	+·09	−·03	+4·06	+5·98	−2·01	−2·04	+·08	−·13	−·19	+·53
May	−·41	−1·28	−0·28	+0·59	−·02	−·07	−·02	−·04	+3·30	+4·26	−1·17	−1·59	+·02	−·06	+·09	+·29
June	·00	−0·02	−0·30	+0·22	+·05	−·02	+·03	−·08	+1·95	+2·75	−0·61	−1·20	+·14	−·05	+·05	+·15
July	−·54	−0·05	−0·24	+0·15	−·04	−·10	−·04	−·06	+0·57	+0·47	−0·28	−0·65	+·17	−·09	+·05	+·15
August	−·49	−0·53	−0·45	+0·04	+·04	+·04	+·02	·00	+0·79	+0·74	−0·30	−1·03	+·01	·00	−·06	−·06
September	−·38	−1·58	−0·24	+0·66	+·15	−·03	−·05	·00	+1·46	+2·90	−0·94	−1·66	+·14	·00	−·06	+·18
October	−·78	−3·07	−1·09	+0·83	+·18	−·13	+·02	+·07	+3·13	+5·64	−0·95	−2·67	+·35	+·66	−·30	·00
November	+·25	−2·04	−2·16	+0·25	−·11	+·23	+·03	+·13	+2·50	+7·35	−0·13	−2·49	+·06	+·63	−·06	−·14
December	+·11	−2·52	−1·85	+0·03	−·22	+·14	+·09	+·15	+2·14	+7·02	+0·05	−2·33	+·26	+·51	−·23	−·24
April to September	−·32	−0·98	−0·23	+0·47	+·09	−·03	·00	−·03	+2·02	+2·85	−0·88	−1·36	+·09	−·05	−·02	+·21
October to March	−·34	−2·72	−1·44	+0·66	−·02	+·18	+·07	+·11	+2·66	+6·42	−0·66	−2·60	+·43	+·49	−·31	−·14
Year	−·33	−1·85	−0·84	+0·57	+·03	+·07	+·04	+·04	+2·34	+4·64	−0·77	−1·98	+·26	+·22	−·17	+·03

TABLE 87—*continued.*

	Temperature of the Air.								Barometric Pressure.							
Coefficients	a_1	b_1	a_2	b_2	a_3	b_3	a_4	b_4	a_1	b_1	a_2	b_2	a_3	b_3	a_4	b_4
January	−3·82	−3·84	+1·34	+1·16	−·17	−·11	−·37	−·14	−·0088	+·0184	+·0128	−·0409	+·0004	+·0066	−·0033	−·0007
February	−3·97	−3·86	+1·37	+1·02	−·09	+·05	−·27	−·30	−·0097	+·0209	+·0160	−·0410	+·0005	+·0050	−·0015	−·0017
March	−3·59	−2·91	+1·29	+0·66	+·05	+·23	−·37	−·18	−·0105	+·0238	+·0161	−·0389	+·0010	+·0022	−·0008	−·0010
April	−3·67	−2·47	+1·11	+0·50	+·34	+·12	−·33	−·08	−·0109	+·0258	+·0152	−·0357	+·0008	−·0002	−·0003	+·0002
May	−3·53	−2·03	+0·88	+0·53	+·36	+·04	−·23	−·05	−·0114	+·0213	+·0136	−·0324	+·0002	−·0017	+·0004	+·0002
June	−2·23	−1·32	+0·67	+0·46	+·19	+·05	−·14	−·05	−·0073	+·0092	+·0145	−·0285	+·0005	−·0037	+·0004	+·0004
July	−1·47	−0·77	+0·58	+0·27	+·03	−·03	−·08	+·02	−·0076	+·0029	+·0140	−·0254	+·0005	−·0027	−·0001	+·0006
August	−1·62	−0·99	+0·64	+0·36	+·07	−·02	−·10	−·02	−·0079	+·0053	+·0135	−·0237	·0000	−·0013	−·0001	−·0007
September	−2·25	−1·51	+0·72	+0·52	+·15	−·05	−·15	−·12	−·0070	+·0116	+·0121	−·0357	−·0003	+·0006	−·0007	−·0004
October	−3·27	−2·53	+0·96	+0·87	+·09	−·05	−·25	−·02	−·0056	+·0193	+·0060	−·0402	+·0002	+·0032	−·0017	−·0004
November	−3·97	−3·35	+1·30	+1·07	−·08	−·17	−·35	+·07	−·0073	+·0200	+·0057	−·0423	+·0014	+·0047	−·0021	−·0006
December	−3·69	−3·62	+1·16	+1·26	−·10	−·23	−·37	+·02	−·0074	+·0187	+·0104	−·0416	+·0011	+·0060	−·0029	−·0008
April to September	−2·46	−1·51	+0·77	+0·44	+·19	+·02	−·17	−·05	−·0087	+·0127	+·0138	−·0312	+·0003	−·0015	−·0001	·0000
October to March	−3·72	−3·35	+1·24	+1·01	−·05	−·05	−·33	−·09	−·0082	+·0202	+·0112	−·0408	+·0008	+·0046	−·0020	−·0009
Year	−3·09	−2·43	+1·00	+0·72	+·07	−·01	−·25	−·07	−·0084	+·0164	+·0125	−·0360	+·0005	+·0016	−·0011	−·0004

151. The variations are in every case very approximately represented by four pairs of terms of the above expression. The subordinate variation expressed by the first pair of terms passes through all its phases in, or has for its period, one day; and those expressed by the second, third, and fourth pairs of terms have periods of twelve hours, eight hours, and six hours respectively. Now the coefficients, when derived as in the present case, from 24 mean hourly observations, are all independent of each other; that is to say, each coefficient is expressed in terms of the twenty-four observations simply, and not as a function of the other coefficients, and the total variation may change in such a way as to give a new value to one coefficient without at all altering the others. For this reason, and for another presently to be stated, we may properly compare the annual variation of the coefficients of one pair of terms, referring to one phenomenon, with the variation of the coefficients of the corresponding pair of terms, referring to another phenomenon. The other condition under which this procedure is allowable is, that taking due account of all modifying circumstances, the causes in operation and their variations must be expressible in the same form, and the coefficients must vary, in each term separately, in the same manner as those which have reference to the observed effects. The advantage of this mode of comparing the several variations over the direct comparison of the curves of figs. 24 to 110 lies in this, that whereas the curves represent variations of any degree of complexity and variety of character, the variations are in this way analysed into component parts, of simple and similar character, and of the same periods for each of the several phenomena to be compared. The coefficients a_1, a_2, a_3, a_4 represent the amplitudes, or half ranges, of simple variations having maxima or minima, according as the signs of a_1, a_2, &c. are positive or negative, at 0 hours, 0 and 12 hours, 0, 8, and 16 hours, and 0, 6, 12, and 18 hours respectively; and the coefficients b_1, b_2, b_3, b_4 represent similar variations having maxima or minima at 6 hours, 3 and 15 hours, 2, 10, and 18 hours, and $1\frac{1}{2}$, $7\frac{1}{2}$, $13\frac{1}{2}$, and $19\frac{1}{2}$ hours respectively; and the variations represented by pairs

of terms a_1, b_1, &c. are equivalent to single similarly simple variations, whose hours of maximum are $(\tan^{-1}\frac{b}{a_1})^\circ \div 15^\circ$; $(\tan^{-1}\frac{b_2}{a})^\circ \div 30^\circ$; $(\tan^{-1}\frac{b_3}{a_3})^\circ \div 45^\circ$, &c., &c., respectively; and if in the manner described in paragraph 131 for the construction of curves representing resultant winds we construct curves to represent the successive monthly values of the pairs of coefficients a_1, b_1, a_2, b_2, &c., setting off the a's upward, and the b's to the right hand, the distance of each point of each figure from the zero point will represent the amplitude of the combined variation, and the angle of inclination, measured by a right-handed rotation, from the upward direction of the line joining each point with the zero point, will represent the hour of maximum of the combined variation, being reckoned, on the figures representing the first, second, third, and fourth pairs of coefficients respectively, at the rate of 15°, 30°, 45°, and 60° per hour.

Such figures are those numbered 144 to 159, and they tell at a glance how in each combined variation the amplitudes and hours of maximum vary from month to month. The point from which a line is drawn to the zero point of each curve represents the average values of the coefficients for the whole year.

152. Let us examine first the a_1, b_1 curves for the four phenomena. In every case the amplitudes of the months 6, 7, 8, 9 are small, and those of the months 11, 12, 1, 2 are large; and, except in the case of barometric pressure, for which the reverse holds, the hours of maximum are earlier in the former months than in the latter. The general similarity of the figures of temperature and east component, when one is twisted into the position of the other, is very remarkably close. The north component curve is of the same type, but more erratic, and that of barometric pressure would be still nearer to the same type if it were inverted about its annual amplitude line as an axis. The general direction of the east component curve being nearly opposite to that of the temperature curve, corresponds to the fact that a minimum of east wind (or maximum of west wind) is nearly contemporaneous with the maximum of temperature. To turn now to the a_2, b_2 curves we find again the amplitudes of the months 6, 7, 8, 9 small, and those of the months 11, 12, 1, 2 relatively large, and except in the case of barometric pressure, for which the reverse holds, the maximum phase occurs earlier in the former than in the latter months; and here too, inverting the barometric pressure curve about its annual amplitude line as axis, the approximation to a common type of form, when the curves are twisted into corresponding positions, is remarkable, though features of departure from the common type are also strongly marked. The a_3, b_3 curves of north component, east component, and temperature are also, when twisted, of a common type; and the first two have small amplitudes for the months 6, 7, 8, 9, and relatively large amplitudes for the months 11, 12, 1, 2. The barometric pressure curve is of different form, but has the two groups of months named placed towards opposite ends of the curve; and in the a_4, b_4 curves, although of very small range, we notice tendencies to the characteristics mentioned as common to the other three sets of curves.

153. But having now learned, by consultation of these figures, that the variations of the coefficients of the different phenomena are related to the annual amplitude lines of the several curves in such a way that, if these be twisted so as to coincide in direction, the curves are more nearly similarly situated than in any other relative positions, we may transform the coefficients into other equivalent ones, which will exhibit in a stronger light the likenesses and differences of variation that we have pointed out. For, representing the angle which corresponds to the hour of maximum of each combined variation for the year of one

subordinate period, that is the angle which the annual amplitude line makes with the upward direction, by β_n, we have—

$$a_n \cos n\,\theta + b_n \sin n\,\theta = A_n \cos (n\,\theta - \beta_n) + B_n \sin (n\,\theta - \beta_n)$$

where $A_n = a_n \cos \beta_n + b_n \sin \beta_n$; and $B_n = b_n \cos \beta_n - a_n \sin \beta_n$;

and calculating A_n and B_n for values of n equal to 1, 2, 3, and 4 in succession, we obtain, in lieu of the coefficients in Table 87, those set down in the following table.

TABLE 88.

	North Component of the Wind.								East Component of the Wind.							
β_n=	259° 53′		145° 50′		66° 48′		45° 0′		63° 14′		248° 45′		40° 14′		170° 0′	
Coefficients	A_1	B_1	A_2	B_2	A_3	B_3	A_4	B_4	A_1	B_1	A_2	B_2	A_3	B_3	A_4	B_4
January	+3·35	+·25	+1·63	+0·40	+·18	+·21	+·22	·00	+6·45	+0·65	+2·43	+0·58	+0·78	+·05	−·17	+·27
February	+3·14	+·06	+1·67	+0·12	+·21	+·16	+·18	·00	+6·72	+0·52	+2·97	+0·40	+1·05	−·11	−·06	+·45
March	+2·34	−·38	+1·26	−0·90	+·35	−·06	+·04	+·04	+7·07	−0·15	+3·20	−0·79	+0·40	−·30	+·32	+·16
April	+2·41	+·32	+0·58	−1·03	+·13	−·33	+·05	−·09	+·717	−0·94	+2·63	−1·14	−0·03	−·15	+·66	−·07
May	+1·33	−·18	+0·57	−0·33	−·07	−·01	−·04	−·02	+5·29	−1·03	+1·90	−0·51	−0·02	−·05	+·38	−·31
June	+0·02	·00	+0·37	−0·01	+·01	−·06	−·03	−·07	+3·33	−0·50	+1·33	−0·13	+0·08	−·13	+·25	−·24
July	+0·15	−·53	+0·28	+0·01	−·11	−·01	−·07	−·01	+0·68	−0·30	+0·70	−0·02	+0·07	−·18	+·25	−·24
August	+0·61	−·39	+0·40	+0·22	+·05	+·02	+·02	−·02	+1·02	−0·37	+1·06	+0·10	+0·01	−·01	+·06	−·09
September	+1·62	−·10	+0·57	−0·41	+·04	−·15	−·03	+·03	+3·25	+0·01	+1·88	−0·28	+0·11	−·09	+·30	−·14
October	+3·16	−·23	+1·38	−0·08	−·04	−·22	+·07	+·03	+6·45	−0·26	+2·83	+0·08	+0·69	+·28	+·16	+·14
November	+1·97	+·60	+1·93	+1·00	+·17	+·19	+·11	+·07	+7·69	+·108	+2·87	+0·78	+0·45	+·44	−·02	−·08
December	+2·46	+·55	+1·56	+1·02	+·04	+·26	+·13	+·04	+7·24	+1·25	+2·15	+0·89	+0·53	+·22	−·09	+·11
April to September	+1·02	−·15	+0·46	−0·26	+·01	−·10	−·02	−·03	+3·46	−0·52	+1·58	−0·33	+0·04	−·10	+·32	−·18
October to March	+2·74	+·14	+1·57	+0·26	+·15	+·09	+·13	+·03	+6·94	+0·51	+2·66	+0·32	+0·65	+·10	+·02	+·17
Year	+1·88	·00	+1·02	·00	+·08	·00	+·06	·00	+5·20	·00	+2·12	·00	+0·34	·00	+·17	·00

TABLE 88—*continued.*

	Temperature of the Air.								Barometric Pressure.							
β_n=	218° 11′		35° 45′		351° 52′		195° 39′		117° 7′		289° 9′		72° 39′		199° 59′	
Coefficients	A_1	B_1	A_2	B_2	A_3	B_3	A_4	B_4	A_1	B_1	A_2	B_2	A_3	B_3	A_4	B_4
January	+5·37	+·66	+1·77	+·16	−·16	−·13	+·40	+·04	+·0204	−·0005	+·0428	−·0013	+·0065	+·0016	+·0034	−·0005
February	+5·50	+·58	+1·71	+·02	−·10	+·04	+·34	+·21	+·0230	−·0009	+·0439	+·0017	+·0049	+·0010	+·0020	+·0011
March	+4·62	+·07	+1·43	−·22	+·02	+·24	+·41	+·08	+·0260	−·0015	+·0420	+·0024	+·0024	−·0003	+·0011	+·0007
April	+4·41	−·33	+1·19	−·24	+·32	+·17	+·34	−·01	+·0279	−·0021	+·0387	+·0027	+·0001	−·0008	+·0002	−·0003
May	+4·03	−·58	+1·02	−·08	+·35	+·09	+·23	−·01	+·0242	+·0005	+·0351	+·0022	−·0016	−·0007	−·0004	−·0001
June	+2·56	−·34	+0·81	−·02	+·18	+·08	+·14	+·01	+·0115	+·0023	+·0317	+·0044	−·0034	−·0016	−·0005	−·0003
July	+1·63	−·30	+0·63	−·12	+·03	−·03	+·08	−·04	+·0060	+·0055	+·0286	+·0049	−·0024	−·0013	·0000	−·0006
August	+1·88	−·22	+0·73	−·08	+·07	−·01	+·11	−·01	+·0083	+·0047	+·0324	+·0030	−·0012	−·0004	+·0004	+·0006
September	+2·70	−·20	+0·88	·00	+·16	−·03	+·17	+·08	+·0135	+·0010	+·0377	−·0003	+·0005	+·0005	+·0008	+·0001
October	+4·13	−·03	+1·29	+·14	+·10	−·04	+·25	−·05	+·0197	−·0038	+·0400	−·0075	+·0031	+·0008	+·0018	−·0002
November	+5·19	+·18	+1·67	+·10	−·06	−·18	+·32	−·16	+·0211	−·0026	+·0419	−·0085	+·0050	·0000	+·0022	−·0001
December	+5·14	+·57	+1·68	+·35	−·07	−·24	+·36	−·12	+·0199	−·0019	+·0427	−·0038	+·0061	+·0007	+·0030	−·0002
April to September	+2·87	−·33	+0·88	−·09	+·18	+·04	+·18	·00	+·0152	+·0020	+·0340	+·0028	−·0013	−·0007	+·0001	−·0001
October to March	+4·99	+·34	+1·59	+·09	−·04	−·05	+·35	·00	+·0217	−·0019	+·0422	−·0028	+·0047	+·0006	+·0022	+·0001
Year	+3·93	·00	+1·23	·00	+·07	·00	+·26	·00	+·0184	+·0001	+·0381	·0000	+·0017	·0000	+·0012	·0000

154. The significance of these numbers, the variations of which from month to month are curved in figs. 160 to 191, will be best conceived by regarding the coefficients for the year, at the foot of the table, as representing an average condition of dynamical equilibrium of the atmosphere in which the average variation of each element is, at this station, the proper complement to the average variations of the other three elements; then if, on comparing the variations at different seasons, we found that the average variations were all proportionally increased or decreased in range, but without any other change of character, we should infer that the actions which constitute the state of dynamical equilibrium were simply intensified or weakened; and similarly, if we found new variations, of whatever character, superimposed upon the average variations, such that the range of the new variation of any one element was always proportional to the range of any other, and the time of occurrence of the phases of each new variation was the same for the different elements, we should infer that new actions had come into operation, which varied only by increase and decrease. Further, if we found that the conditions described were not completely, but only in great part, fulfilled, we should look for causes of a certain degree of simplicity and of constancy in their mode of operation; but if we found the variations of one element subject to changes of range and character that seem to have no relation to the contemporaneous changes in the variations of the other elements, we should feel assured that the efficient causes are either in themselves highly complex, or are very various in their mode of operation, and that no theory, simple as well in its development as in its conception, can possibly be adequate to the explanation of such phenomena. But on examination of the figs. 160 to 191 we find that in fact there is very much that is indicative of the simpler kind of causation. To look first at the two principal elements of temperature variation, as represented by the curves of variation of A_1 and A_2, we observe that the curves are of similar form, having a minimum at the middle of the year, and departing little from a maximum between November and February, and with gradual and regular progression in the intermediate months on both sides of the minimum. The ratio of the range (1·14) of the A_2 curve to that of the A_1 curve (3·87) is 0·29, which is nearly the same as the ratio (0·31) between the mean value for the year (1·23) of A_2 to the mean value (3·93) of A_1. From the very close agreement of these ratios (0·29 and 0·31) we infer that this, the principal part of the temperature variation, is at all seasons of the same type as the diurnal variation for the year; and the B_1, B_2 curves have also nearly similar forms, with ranges in the proportion of 1 to 0·48. We turn now to the A_1 and A_2 curves of the north and east components of the wind, and find the curves to be of like general character to those of temperature, but having secondary minima of slight depression, in the case of the north component, in November and December, and, in the case of the east component, in January and December; also we find that the mean values for the year (1·02 and 2·12) of A_2 have the ratios 0·54 and 0·41 to the respective mean values (1·88 and 5·20) of A_1; and, again, that the ratio of the range of variation of A_2 to that of A_1 is for the north component 0·50 $\left(=\frac{1\cdot65}{3\cdot33}\right)$, and for the east component 0·36 $\left(=\frac{2\cdot50}{7\cdot01}\right)$. If these ratios had all been identical, we should have said that the type of this part of the wind variation was invariable, the range of variation only being subject to change with change of season; and as they differ only within the moderate limits 0·36 to 0·54, we may form from them some estimate of how much of the variations should be regarded as of an invariable type, and how much subject to change of type. In the case of the B_2 curves of

the north and east components the movements are so closely allied as to suggest an unmistakeable identity of causation. The diurnal inequalities of the combined subordinate variation of the wind expressed by the terms $B_2 \sin (2\theta + \beta_2)$ for the two components would be represented graphically, both in direction and velocity, by the *radii vectores* of ellipses, which would be of similar form for every part of the year,—ellipses that would contract, vanish, and expand together, in each of two rectangular directions. That such a variation could be the result of the action of two or more independent causes is extremely improbable. The curves in question have principal maxima in November and December, principal minima in April, secondary maxima in August, and secondary minima in September. The B_1 curve of the east component is also very like those just described, but that of the north component has but little definiteness of character. Both the absolute values of A_3 and A_4, and the variations of A_3, B_3, A_4, and B_4, except in the case of barometric pressure, are too small to be discussed for any importance of their own, but they may be useful for confirmation or refutation of any idea that may be conceived as explanatory of the more prominent phenomena. The barometric pressure curves, whilst possessing much in common with those of the other phenomena, have distinct characteristics of a bold and clear type that belong to them alone. In the A_2, A_3, and A_4 curves of this element the occurrence of low values about the middle of the year, and high values about the beginning of the year, is accompanied by a simpler intermediate progression than in the A curves of the other phenomena. Such occurrence also forms a principal feature of the A_1 curve, which has also, like the A_1 curve of the east component, maxima in April and November, and a secondary minimum intervening; and upon it there is superimposed a variation of a distinct character that either raises the values of A_1 about April, or depresses them about October or November, or does both. The A_3 and A_4 curves are both of a simple type, and the first has a greater relative range than the corresponding curves of the other elements. The minimum values of A_3 and A_4 occur in June, whilst those of A_1 and A_2 are delayed till a month or more later. The B_1 curve, if inverted, would present a close resemblance to the A_1 and A_2 curves of the east component of the wind. Still speaking of barometric pressure, the B_2 curve if put backward three and a half months would have a form intermediate between those of the A_1 and A_2 curves; and if put back seven months, though not quite similar in form, it would have inflexions corresponding fairly to all the four principal ones of the B_2 curves of the north and east components of the wind. Of the B_1 curve of barometric pressure we may, speaking roughly, say that it has positive ordinates when the B_1 curves of the other meteorological elements have negative ordinates, and *vice versâ*, and similarly with respect to the respective B_2 curves. These relations correspond to the fact which we noticed in considering figs. 144 to 159, that generally the maximum phases of barometric pressure occur early when those of the other phenomena occur late, and *vice versâ;* and taken together with the very considerable degree of similarity that exists between the A_1 and A_2 curves of barometric pressure and those of the other elements, they lead to this unexpected result,—that whereas a growth or decadence of the normal diurnal variations of the elements, north and east components and temperature, is accompanied by a considerable growth or decadence of the normal diurnal variation of barometric pressure, the variations represented by the terms $B_1 \sin (\theta + \beta_1)$ and $B_2 \sin (\theta + \beta_2)$, taken together or separately, have no simple relation to each other, and tend more to opposition of movement than to correspondence. By means of these figures very many of the numerous conditions that must be satisfied by any theory of

the general phenomena are brought clearly before the mind; and it is evident from the differences between the curves of barometric pressure and those of the other phenomena that a theory of barometric movements which depends on other phenomena, as exhibited at this one station, must leave much yet to be explained. At the same time the intimate relations subsisting between temperature and wind variations are very clearly indicated. The common theory of land and sea breezes explains satisfactorily the chief of these relations.

155. Applied in the case of Bombay the theory is as follows:—As the sun rises in the heavens the soil to landward of Bombay becomes heated by solar radiation, and in its turn heats the air above it, which in consequence expands and rises, causing an overflow in the upper regions of the atmosphere; a quantity of air being thus removed, the barometric pressure near the heated soil is diminished, and air flows in from the cooler regions to seaward to equalize the pressure. The flow continues above and below till the soil has attained nearly its mean temperature, or the temperature of the sea, which varies comparatively little in the course of the day. During the interval the temperature of the soil and the velocity with which the air flows both pass through their maxima, and that nearly simultaneously. At this period the lower flow of air at Bombay—speaking of the diurnal variation by itself—is a westerly wind, commencing about 11 a.m. or noon, with a maximum velocity at 3 or 4 p.m., and ceasing about 10 p.m. From this time the air begins to flow seaward, reaching its maximum velocity about 8 a.m., and ceasing about 11 a.m., or noon. The latter movement is thus explained by the theory; in the same manner that the soil absorbed more of the sun's rays than the sea and thus became heated, so it radiates more heat into space, and after both have acquired the same temperature it cools the more rapidly; the air above it then becomes cooled and condensed, and fresh air flows in—down the incline as it were—in the upper regions of the atmosphere. In consequence the barometric pressure increases, and the air begins to push it itself out to seaward, where the same cause has been operating, but less effectually, to cool and condense the air. The soil inland becoming by its superior radiation much cooler than the sea, the land breeze continues to flow until the sun has again risen, and radiated sufficient heat upon the soil to restore the equilibrium of temperature between it and the sea; after which the same cycle of changes is again gone through day by day. It must not be supposed that the theory professes to account for the actual daily variations of barometric pressure; all that it requires is that, superposed upon the diurnal variation of barometric pressure proper to the Indian Peninsula, there shall be a diurnal variation—it may be of much smaller magnitude—having a character approaching to opposition to seaward and to landward of Bombay. It will thus be seen that although the *absolute* maxima and minima of barometric pressure may occur nearly simultaneously over the whole of India, the average difference of longitude of different places being less than *one hour*, yet a relative or local difference of pressure such as is required by the theory may well have place at the same time.

156. To test conclusively whether such a difference, which would be the measure of the secondary producing cause of the land and sea breezes, really exists, accurate barometric observations at suitably situated stations would be indispensable; but, failing such a test, the curves of Plates XXI. and XXII. afford remarkable evidence of a small variation of barometric pressure at Bombay which in phase and amplitude corresponds closely to the principal

element of the east component of the wind. It has already been remarked that fig. 167, when inverted, is in these respects very similar to fig. 161, and the likeness would be still closer if for the ordinates of the barometer curve were taken the projections of the *radii vectores* of fig. 147, on a line inclined 248° 44′ to the north (or upward) direction, by which means the fig. 167, whilst little altered in form, would be depressed so as to lie nearly wholly below the zero of the curve form. It would then be seen that a minimum of this element of the diurnal variations of barometric pressure occurs simultaneously with a minimum of the element of the east component of the wind represented by fig. 161, and that the one set of amplitudes is approximately proportional to the other set at all seasons of the year. But if we compare the complementary elements of the two variations, viz., those represented by figs. 163 and 165, in the expectation that the departure from symmetry of form of the former curve in the first and second half years might be accounted for by a similar relation of the east component of the wind to the barometric pressure to that which is approximately exhibited by curves 161 and 167, we find a directly contrary result; that is, the wind which accompanies the movement of the barometer through its maximum in the one case is that which accompanies the movement of the barometer through its minimum in the other, and *vice versâ*.

PART II.

OBSERVATORIES AT FIVE MILITARY STATIONS, AND THEIR OBSERVATIONS.

157. *System of observation: its origin and nature.*—In the year 1851 Her Majesty's Home Government instituted a system of meteorological observations at a number of military stations occupied by corps of the Royal Engineers in the United Kingdom and in the Colonies. The observations were conducted on a uniform system under the direction of officers of the Royal Engineers. In the same year the Lords of the Admiralty determined to carry out the same system at some other stations; and the Honourable Board of Directors of the East India Company responded to an invitation to co-operate by establishing a number of observatories in India. Of these, five were in the Bombay Presidency, four—at Belgaum, Poona, Deesa, and Kurrachee—in charge of the senior medical officers of the European hospitals at the several stations, and under the administration of the medical departments, and one—at Bombay (Colába)—in charge of the Superintendent of the Colába Observatory; and all five have been kept up till the present day.

158. The system comprises two sets of observations every day at 9.30 a.m. and 3.30 p.m., and a complete set of 24 hourly observations for one day in every month, and the instruments and phenomena noted at each observation include the barometer, dry and wet bulb thermometers, direction of wind, cloudiness, and rainfall; and once a day the maximum and minimum thermometers in the shade, the maximum thermometer exposed to the sun's rays at daytime, and the minimum thermometer laid upon grass exposed to the sky at night. The observations are registered upon printed forms, which, when filled up, are regularly forwarded by the heads of the medical departments to the Superintendent of the Colába Observatory, for the purpose of having the calculations made by the observers subjected to examination, and for the compilation of abstracts of results; and once a year the registers and compilations are sent by the Superintendent to Government to be forwarded to Her Majesty's Secretary of State for India.

159. *Recent collection together at Colába of long series of observations.*—Until recently, when occasion arose for collecting at Colába the office copies of the registers kept at the provincial observatories, no extended series of these observations were available in India for comparison with each other; and although it has not been practicable to obtain complete copies, a very large body of observations has been brought together, extending—with the exceptions noted in the following statement—over the 17 years from 1856 to 1872.

160. Statement showing the deficiencies in the 17 years' records of meteorological observations at the five military stations:—

BELGAUM.

Daily Observations.

1856, January to April.—No observations of cloudiness.
1856, January to December.—No readings of maximum and minimum thermometers.
1857, January to March.—No readings of maximum and minimum thermometers.
1863, July.—Rejected because figures are extensively and suspiciously altered.

Hourly Observations.

1856, January to December.—No observations.
1858, December.—No observations.
1858, May to November.—No entries under column headed "Elastic force of vapour."
1859, January.—No entries under column headed "Elastic force of vapour."
1862, November.—No observations.
1863, December.—Rejected because figures are suspiciously altered.
1865, November.—Incomplete. No observations for night hours.
1866, November and December.—No observations.
1867, January.—No entries under "Barometer corrected," nor under "Air thermometer corrected."

POONA.

Daily Observations.

1858, June.—Incomplete.
1863, December.—No readings of maximum thermometer.

Hourly Observations.

1856, January to May.—No observations.
1858, July.—Entries of readings of barometer manipulated, and therefore rejected.
1870, November.—No observations.

BOMBAY.

Daily Observations.

No deficiencies.

Hourly Observations.

No deficiencies.

DEESA.

Daily Observations.

1856, January to May.—No observations.
1857, May to December.—No readings of barometer.
1858, January to October.—No readings of barometer.
1860, July to November.—No observations.
1867, October to December.—No observations.
1868, January.—No observations.

Hourly Observations.

1856, January to May.—No observations.

1856, June to December.—No entries under "Elastic force of vapour."

1857, February, July, September, October, and December.—No observations.

1857, May, June, August, and November.—No readings of barometer.

1857, January, April, May, June, August, and November.—No entries under "Elastic force of vapour."

1858, March.—No observations.

1858, January to December.—No readings of barometer, and no entries under "Elastic force of vapour."

1859, April.—No observations.

1859, December.—No entries under "Air thermometer corrected."

1859, January and February.—No readings of barometer.

1859, March, October, and December.—No entries under "Barometer corrected."

1859, January to March, May, June, and December.—No entries under "Elastic force of vapour."

1860, June to October.—No observations.

1860, January and May.—No entries under "Barometer corrected."

1860, January, April, and May.—No entries under "Air thermometer corrected."

1860, January to May.—No entries under "Elastic force of vapour."

1861, May.—Readings of barometer incomplete.

1862, February to April.—No entries under "Air thermometer corrected."

1863, October.—No observations.

1866, November.—No observations.

1866, June.—Incomplete.

1866, October.—Corrected readings of barometer rejected because column for uncorrected readings is left blank.

1867, March, April, and October to December.—No observations.

1868, January to March.—No observations.

KURRACHEE.

Daily Observations.

1856, January to March.—No observations of cloudiness.

1866, September to November.—No readings of barometer.

1867, October to December.—No observations.

1868, January and February.—No observations.

1872, October to December.—No readings of barometer, air thermometer, or maximum and minimum thermometers.

Hourly Observations.

1856, January, February, April, and May.—No observations.

1856, March.—No entries under "Elastic force of vapour."

1861, June and July.—No observations.

1866, September to November.—No readings of barometer.

1866, September and October.—No entries under "Elastic force of vapour.'

1866, October.—Readings of air thermometer incomplete.

1867, October to December.—No observations.

1868, January and February.—No observations.

1868, March.—No entries under "Elastic force of vapour."

Whilst the work of reduction of the observations was in hand, additional materials became available for later years than 1872, and these have been made use of whenever the incorporation of them did not involve the application of ramifying corrections that could only be applied with great labour.

161. In regard to the matters of fact stated in the first part of this paper, it is right to explain here that to a great extent they come within the range of the writer's personal knowledge; whilst in all that follows, excepting what relates to the Colába observations, the part allotted to him is simply that of compiler of documents temporarily placed in his hands, and utilizer of their contents.

162. *Geographical position and height of stations.*—The geographical positions and heights above mean sea level of the several observatories are given as follows:—

Station.	Belgaum.	Poona.	Bombay.	Deesa.	Kurrachee.
Latitude - - -	15° 52′ North	18° 28′ North	18° 54′ North	24° 12′ North	24° 47′ North
Longitude - -	74·42 East	74 10 East	72 48 East	72 17 East	67 4 East
Height above mean sea level -	2,260 feet	1,992 feet	37 feet	408 feet	40 feet

163. *Change of instruments: index errors.*—Each observatory possesses tables of corrections for index errors of the various thermometers and of the barometer, which corrections are regularly applied to the observations; but in general no one appears to know on what authority the errors rest, nor whether they refer in every case to the instruments at present in use. The barometers were changed at Kurrachee in December 1866, and at Bombay sometime before 1865—probably at the beginning of 1860, when the old corrections cease to be applied to the observations.

164. *Observers.*—From the commencement of the system the observers at the out-stations have been European soldiers, who were drafted off from their regiments for the duty; and before entering upon this duty they were invariably put through a course of practical training at the Colába Observatory. At Bombay the observer was a well-trained Brahmin or Purbhoo, who acted also as the immediate instructor of soldiers under training.

165. *Belgaum* lies about 50 miles eastward from the sea coast, and occupies undulating ground that has an elevation above the mean sea level varying from 2,100 to 2,260 feet. On the higher ground is situated the European general hospital, within the compound of which is the Meteorological Observatory. The station, as well as some low-lying ground to the south and east of it which is wholly under rice cultivation, is on the watershed of the Márkándeya river. The surface of the station exhibits laterite overlying trap rock, which in many places outcrops it: in the valleys the surface is of black soil. In many parts there are beds of solid laterite of very great thickness. Rain-water is not retained in the soil, but quickly passes away by percolation. The station, with the exception of the site of the barracks and the ground lying north-west and south-west of it, is well clothed with trees, but the surrounding country is generally bare. The self-registering thermometers are placed in a wooden revolving stand (of description shown in plates 3 and 4 of James's Instructions), at a distance of 18½ feet from the nearest building, and four feet from the ground: they are fully exposed to the air, and protected from the sun's rays, but it is impossible to prevent rain from getting at them during the revolving storms which occur at the commencement of the monsoon. The readings of the thermometers are supposed to be too high, as the construction of the stand is not adapted to a tropical sun. The barometer and dry and wet bulb thermometers are in a shed erected in the north-north-east verandah of the hospital guard-house. The shed is of dimensions 13 by 8 by 6 feet, and is constructed of wooden bars two inches apart; it has a flagged floor, and a post in the middle extending from floor to roof: this post supports the barometer on one side and the dry and wet bulb thermometers on the other, the latter being four feet seven inches from the floor, and respectively two feet seven inches and three feet one inch from the wall.

166. *The Poona Observatory* is said to be a passage through the middle of the hospital building which lies to the southward of the Wanowree Barracks. It has latticed doors at the north and south ends to admit the air. The thermometers are fixed on horizontal blocks of wood projecting from the wall, with their bulbs about 1½ inch off the wall and about five feet from the ground, and having a moderate circulation of air about them. The barometers are also suspended from a strong wooden projection from the wall. The surrounding country is a level plain, surrounded—except towards the east, in which direction the plain of the Deccan extends—at a distance of six miles, more or less, by high hills. The cantonment is well planted with trees. Trap rock appears close to the surface of the ground.

167. *At Bombay*, in lieu of a separate military observatory, it was arranged that special observations on the Royal Engineers' plan should be taken, at the Colába Observatory, of which an account has been already given in Part I., paragraphs 9 to 17. Until the end of 1865 all the thermometers were observed in the revolving thermometer stand described in paragraph 59, and since that time in the venetianed cage then erected in the thermometer shed (see paragraph 53).

168. *Of Deesa* we are told: The building for the observatory is a shed nine feet square inside, with walls built round two feet high, and bamboo-work from that height to the roof.

The roof is double, the outer one being tiled, and the inner—about two feet below the outer—of wood; and a verandah is formed round the room by a continuation—made of bamboo matting—of the slanting roof. This projection from the roof, which is five feet in breadth, reaches to within five feet of the ground. On the south-west side are placed two additional bamboo screens. The floor of the room is of cement. The thermometer stand is in the middle of the building, and about four feet from the ground; its frame is of wood, and the back and front of wire, allowing a free current of air to pass through and round the instruments.

The observatory is situated within the compound of the European Infantry Hospital, in the east portion of the camp, and about 247 feet in rear of the middle of the hospital; and there is a double row of trees between the hospital and the observatory, about 82 feet from the latter, which appears to interfere with the free access of winds from the S.W. and W.N.W. The soil in and around Deesa is light and sandy, and the surrounding country is jungley, consisting chiefly of small underwood. A range of hills appears to the north-eastward of the camp about 12 miles distant, and there is one small outlying hill about seven miles east of the camp.

169. *Of Kurrachee* it is said: The geological formation is tertiary, composed of strata of comminuted marine shells alternating with layers of arenaceous and argillaceous limestone, and with beds of a conglomerate consisting of rolled nodules of foraminiferous limestone, which appears in many places at the surface. The surface soil is alluvial, covered in parts with drift sand of a silicious and micaceous character. The subsoil is chiefly clay, highly impregnated with saline matter, and with sandstone lying at a greater depth.

Except in the vicinity of the Layári river at the northern end of the camp, which is the only cultivated spot, the aspect of the surrounding country is that of a barren waste, nearly flat, relieved towards the eastern and northern limits of the town land by a range of very low rocky hills. This part of Sind is within volcanic range, as is shown by the hot springs issuing from the coralline rock in the crater-like hollow of Mugger Peer, eight or nine miles due north of Kurrachee, the mud springs on the border of the Belooch territory to the westward, the upheaval of the Ullah-bund, and the submersion at Lukput, on the eastern side of the delta of the Indus, in the earthquake of the year 1819.

The cantonment stands about five or six miles to the eastward of the harbour at Keamáree, and runs parallel to the sea for a distance of about two miles in a direction from S.E. to N.W. The position on which it is situated bears evidence of having at one time been submerged, and was probably in the course of one of the mouths of the Indus.

The Napier lines is at the S. and S.E. end of the cantonment, and is nearly on a dead level, and so little above the sea that rain lies where it falls; this, coupled with the retentive nature of the subsoil, renders the camp very little better than a swamp after a very moderate fall.

The observatory is erected in the Napier Hospital, which is built on a low rocky ridge, at an altitude of about 40 feet above sea level, and half a mile from the barracks in a south-easterly direction, with a nearly W.S.W. aspect, and exposed to the prevailing winds, which are westerly and from the sea.

The anemometer tower is situated on the highest part of the ridge on which the hospital stands, distant about 300 yards to the rear or eastward side; it is a stone-built structure, 10 feet square and 16 feet 6 inches high, with perpendicular walls and flat roof. The only instrument in this building is Aidie's self-registering anemometer and pluviometer.

The thermometer shed is erected at the northern end of the hospital compound, on the plan of the one at the Colába Observatory, being a wooden framework 12 feet square and 13 feet high; the sides are frames covered with matting, and made to open upwards, so that they can be raised or lowered at pleasure; this structure surrounds a venetianed wooden case three feet square and eight feet high.

The thermometers in the shade are placed on a rack four and five feet from the ground, and have a free circulation of air around them, and are well protected.

Barometric Pressure.

170. *Mean barometric pressure and secular variation.*—The mean barometric pressure for each year of complete observations is shown for the several stations in the following table, the means being derived from the two daily observations made at the hours 9.30 a.m. and 3.30 p.m.

Table 89.

Year.	Belgaum.		Poona.		Bombay.		Deesa.		Kurrachee.	
	Mean Pressure.	Excess above General Mean.	Mean Pressure.	Excess above General Mean.	Mean Pressure.	Excess above General Mean.	Mean Pressure.	Excess above General Mean.	Mean Pressure.	Excess above General Mean.
1856	27·369	+·046	27·892	+·036	29·820	−·019			29·846	−·028
1857	27·326	+·003	27·873	+·017	29·841	+·002			29·871	−·003
1858	27·331	+·008			29·846	+·007			29·855	−·019
1859	27·325	+·002	27·848	−·008	29·850	+·011	29·561	+·054	29·933	+·059
1860	27·324	+·001	27·856	·000	29·810	−·004			29·902	+·028
1861	27·322	−·001	27·847	−·009	29·800	−·014	29·519	+·012	29·846	−·028
1862	27·302	−·021	27·845	−·011	29·790	−·024	29·496	−·011	29·851	−·023
1863			27·856	·000	29·797	−·017	29·497	−·010	29·850	−·024
1864	27·345	+·022	27·882	+·026	29·837	+·023	29·538	+·031	29·939	+·065
1865	27·338	+·015	27·874	+·018	29·821	+·007	29·517	+·010	29·846	−·028
1866	27·335	+·012	27·857	+·001	29·828	+·014	29·535	+·028		
1867	27·337	+·014	27·846	−·010	29·829	+·015				
1868	27·331	+·008	27·852	−·004	29·841	+·027				
1869	27·308	−·015	27·842	−·014	29·818	+·004	29·519	+·012	29·998	+·006
1870	27·289	−·034	27·837	−·019	29·800	−·014	29·501	−·006	29·978	−·014
1871	27·304	−·019	27·855	−·001	29·808	−·006	29·515	+·008	29·981	−·011
1872	27·292	−·031	27·834	−·022	29·800	−·014	29·515	+·008		
General Means	27·323		27·856		29·839		29·507		29·874	
					29·814				29·992	
Additional Years 1873	27·303	−·020	27·844	−·012	29·819	+·005	29·522	+·015	29·963	−·029
Additional Years 1874	27·298	−·025	27·841	−·015	29·814	·000	29·526	+·019	29·981	−·011

171. There is an evident difference in the two barometers used at Kurrachee and in the two used at Bombay, and the two general means for the former station as well as the corresponding excesses refer to the periods 1856 to 1866 (August), and 1866 (December) to 1872, and those for the latter station to the periods 1856 to 1859, and 1860 to 1872, periods during which it is probable that no change of barometer took place. The general mean is in every case the mean of the 12 monthly means derived from the observations of incomplete as well as of complete years, and it will not necessarily be the same as the mean of the complete years only. Either Kurrachee is already far enough removed from the equator to be affected by barometric disturbances much more than the four more southerly stations, or else the observations taken there are, for some reason, less comparable than elsewhere; for it will be noticed that there is some degree of parallelism in the movements of the barometer from year to year, as shown at the first-mentioned four stations, whilst at Kurrachee the movements are larger and resemblance is found only in isolated short periods. In particular we would direct attention to the correspondence of movement shown in the curves of figs. 263 to 266, which represent the excesses of Table 89, in the years 1861 to 1865 and 1868 to 1873, in the latter case especially with regard to the three southernmost stations, but attaching also to the excesses of the years 1869 to 1871 for Kurrachee. If we take the means of the yearly excesses at all the stations, Belgaum, Poona, Bombay, and Deesa, and include the regular years 1869 to 1871 at Kurrachee, we find indications similar to those already pointed out for Bombay alone, of a decennial period having its maximum a quarter of a period in advance of the maximum of the sun-spot period. The means are as follows: for 1856 to 1859, + ·012; for 1860 to 1863, — ·007; for 1864 to 1868, + ·013; and for 1869 to 1872, — ·010 inch. The year 1869 is one of intermediate values, which at Belgaum and Poona are somewhat more advanced than at the three other stations, and in the grouping it is more effectively placed in the last period, whilst with Bombay alone it went with the preceding one. We may remark also that the high barometer at Kurrachee in 1864 is in agreement with, though also in exaggeration of, what appears for the other stations; also that the falling movement at Kurrachee from 1859 to 1861 becomes smaller at the next station (Deesa) to southward, still smaller at Bombay further south, and has disappeared at Poona and Belgaum.

172. *Annual variation.*—In the next table we give the excesses, for each station, of the mean barometric pressure in the several months above the mean of the year; first, as deduced from observations taken daily at the hours 9.30 a.m. and 3.30 p.m.; and secondly, after correction for the diurnal inequality at those hours.

TABLE 90.

		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
From Observations at 9.30 a.m. and 3.30 p.m.	Belgaum -	+·094	+·067	+·031	−·019	−·048	−·098	−·096	−·062	−·032	+·009	+·065	+·089
	Poona -	+·120	+·086	+·039	−·015	−·065	−·146	−·141	−·092	−·044	+·029	+·104	+·129
	Bombay -	+·129	+·096	+·050	−·013	−·053	−·156	−·159	−·103	−·040	+·022	+·094	+·131
	Deesa -	+·208	+·151	+·086	−·019	−·088	−·241	−·268	−·193	−·078	+·050	+·177	+·218
	Kurrachee -	+·246	+·182	+·128	−·019	−·129	−·271	−·306	−·226	−·096	+·056	+·118	+·256
Corrected for Diurnal Inequality.	Belgaum -	+·089	+·064	+·030	−·016	−·049	−·096	−·095	−·062	−·025	+·011	+·062	+·089
	Poona -	+·118	+·085	+·043	−·013	−·063	−·145	−·142	−·096	−·043	+·029	+·102	+·128
	Bombay -	+·127	+·097	+·052	−·012	−·054	−·157	−·158	−·096	−·038	+·020	+·090	+·126
	Deesa -	+·201	+·144	+·083	−·024	−·091	−·234	−·261	−·190	−·070	+·050	+·176	+·215
	Kurrachee -	+·239	+·178	+·117	−·016	−·133	−·271	−·304	−·222	−·089	+·064	+·189	+·251

173. The corrections are found from the diurnal inequalities at the several hours in each month, as given in Tables 91 to 95, paragraph 175; they are the means of those inequalities for the hours 9 a.m. and 10 a.m., and 3 p.m. and 4 p.m., and are applied subtractively. The effect of this operation is to give us values of the monthly inequalities nearly equivalent to what would have been found if the daily observations had been taken every hour instead of only at 9.30 a.m. and 3.30 p.m. It will be observed that the uncorrected and corrected numbers are almost identical; hence we infer that observations at 9.30 a.m. and 3.30 p.m. suffice for a satisfactory determination of the annual variation of barometric pressure. For Bombay, instead of applying corrections, the values of the monthly inequalities given by 26 years of hourly observations (see Table 1) are entered in the second part of the table.

174. The numbers in Table 90 are curved in figs. 283 to 287, the uncorrected inequalities in black ink, and the corrected inequalities in red ink. The figures are all of similar form, having values near the maximum from December to January in the case of Kurrachee, and for November to January at the other stations, and values near the minimum in June and July, and with gradual progressions from maxima to minima and from minima to maxima. The range between the greatest and least monthly means increases with the latitude, and is about three times as great at Kurrachee as at Belgaum: its value at the several stations, taken in the order of their latitudes, viz., Belgaum, Poona, Bombay, Deesa, and Kurrachee, are 0·185, 0·273, 0·285, 0·476, and 0·555 inch respectively, Any influence that height of the station has upon the annual range—and we cannot suppose the pressure of a column of more than 2,000 feet in height to be exactly the same at all seasons—does not alter the order which the numbers follow as affected by change o latitude.

175. *Diurnal variation.*—In Tables 91 to 95 are shown, for the several stations, and for each month and the whole year, the excesses of the mean barometric pressures at the several hours of the day above the mean barometric pressure for the 24 hours; and the number of complete days' observations, being generally not more than one in each month of each year, from which the means are derived.

TABLE 91.

BELGAUM.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	+·012	+·028	+·050	+·066	+·065	+·046	+·022	−·010	−·033	−·049	−·051	−·044	−·033	−·016	·000	+·010	+·013	+·008	−·002	−·008	−·017	−·025	−·025	−·014	16
February	+·005	+·025	+·046	+·061	+·058	+·045	+·023	−·005	−·031	−·046	−·052	−·045	−·033	−·016	+·001	+·016	+·018	+·014	+·003	−·009	−·016	−·023	−·022	−·011	17
March	·000	+·022	+·045	+·059	+·059	+·048	+·027	−·001	−·025	−·046	−·055	−·048	−·035	−·017	−·002	+·014	+·020	+·014	+·005	−·008	−·016	−·022	−·023	−·015	17
April	+·012	+·027	+·046	+·056	+·055	+·045	+·028	−·001	−·030	−·049	−·056	−·049	−·032	−·017	−·007	+·009	+·016	+·015	+·002	−·008	−·017	−·019	−·015	−·004	17
May	+·014	+·028	+·048	+·055	+·055	+·035	+·017	−·002	−·024	−·041	−·051	−·047	−·033	−·019	−·008	+·007	+·013	+·016	+·009	−·004	−·014	−·020	−·018	−·006	17
June	−·006	+·006	+·020	+·030	+·026	+·020	+·011	·000	−·011	−·023	−·029	−·028	−·017	−·005	+·007	+·013	+·022	+·021	+·012	+·001	−·007	−·016	−·021	−·022	17
July	−·008	+·002	+·016	+·024	+·030	+·024	+·016	+·001	−·010	−·019	−·028	−·027	−·020	−·009	+·004	+·014	+·019	+·017	+·011	−·001	−·009	−·017	−·019	−·013	17
August	−·004	+·009	+·026	+·038	+·038	+·030	+·016	+·001	−·015	−·027	−·037	−·031	−·022	−·008	+·006	+·020	+·026	+·020	+·006	−·006	−·016	−·025	−·026	−·021	16
September	−·007	+·012	+·032	+·042	+·037	+·026	+·010	−·015	−·033	−·047	−·049	−·039	−·029	−·013	+·005	+·021	+·029	+·022	+·014	+·005	−·004	−·008	−·011	·000	16
October	+·004	+·021	+·040	+·050	+·048	+·032	+·009	−·016	−·038	−·049	−·048	−·036	−·020	−·004	+·011	+·020	+·024	+·015	+·006	−·006	−·013	−·021	−·024	−·015	16
November	+·011	+·029	+·049	+·065	+·064	+·042	+·014	−·015	−·039	−·051	−·054	−·044	−·032	−·014	+·005	+·017	+·023	+·015	+·005	−·004	−·015	−·022	−·024	−·015	13
December	+·002	+·020	+·041	+·053	+·056	+·040	+·017	−·013	−·035	−·046	−·049	−·039	−·029	−·014	+·002	+·014	+·019	+·011	+·008	−·001	−·010	−·016	−·016	−·005	13
Year	+·003	+·019	+·038	+·050	+·049	+·036	+·017	−·007	−·027	−·041	−·047	−·040	−·028	−·013	+·002	+·014	+·020	+·015	+·006	−·004	−·013	−·020	−·021	−·012	
June to August	−·006	+·006	+·021	+·031	+·031	+·025	+·014	+·001	−·012	−·023	−·031	−·029	−·020	−·007	+·006	+·016	+·022	+·019	+·010	−·002	−·011	−·019	−·022	−·019	

TABLE 92.

POONA.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	+·008	+·027	+·049	+·068	+·068	+·039	+·007	−·025	−·051	−·071	−·070	−·049	−·027	−·006	+·016	+·036	+·042	+·026	+·010	−·006	−·021	−·033	−·037	−·011	20
February	+·009	+·028	+·048	+·066	+·067	+·040	+·011	−·017	−·048	−·070	−·072	−·055	−·034	−·011	+·013	+·036	+·042	+·028	+·015	·000	−·019	−·033	−·031	−·013	20
March	+·011	+·033	+·050	+·064	+·062	+·034	+·008	−·024	−·053	−·075	−·081	−·059	−·035	−·009	+·015	+·037	+·045	+·033	+·019	+·001	−·016	−·030	−·029	−·005	21
April	+·018	+·037	+·054	+·066	+·060	+·032	+·004	−·024	−·050	−·073	−·076	−·052	−·031	−·007	+·015	+·034	+·042	+·029	+·012	−·003	−·019	−·034	−·030	−·011	21
May	+·015	+·030	+·045	+·055	+·053	+·028	+·002	−·022	−·043	−·060	−·067	−·045	−·027	−·007	+·017	+·035	+·040	+·026	+·012	−·002	−·016	−·030	−·026	−·006	21
June	−·004	+·012	+·024	+·036	+·035	+·016	·000	−·014	−·030	−·043	−·043	−·029	−·013	+·004	+·020	+·033	+·035	+·025	+·011	·000	−·013	−·026	−·026	−·008	22
July	−·006	+·006	+·021	+·037	+·036	+·021	+·005	−·012	−·026	−·040	−·039	−·026	−·009	+·005	+·018	+·031	+·031	+·019	+·009	−·003	−·015	−·027	−·025	−·012	21
August	−·003	+·013	+·025	+·043	+·044	+·024	+·008	−·008	−·026	−·040	−·041	−·028	−·011	+·004	+·019	+·033	+·034	+·020	+·005	−·008	−·022	−·035	−·035	−·022	21
September	+·005	+·020	+·035	+·050	+·045	+·029	+·007	−·016	−·037	−·056	−·056	−·038	−·020	−·001	+·016	+·036	+·038	+·024	+·012	−·002	−·015	−·029	−·027	−·013	20
October	+·008	+·026	+·043	+·058	+·058	+·031	+·004	−·022	−·045	−·063	−·064	−·045	−·024	−·004	+·017	+·038	+·041	+·028	+·012	−·003	−·016	−·030	−·029	−·011	20
November	+·003	+·027	+·047	+·065	+·063	+·036	+·006	−·021	−·044	−·066	−·065	−·047	−·028	−·006	+·016	+·038	+·040	+·023	+·008	−·008	−·022	−·035	−·030	−·014	18
December	+·004	+·024	+·045	+·062	+·063	+·036	+·007	−·020	−·043	−·065	−·068	−·049	−·028	−·008	+·008	+·035	+·043	+·028	+·013	−·002	−·015	−·027	−·026	−·018	20
Year	+·007	+·024	+·041	+·056	+·055	+·031	+·006	−·018	−·041	−·060	−·061	−·043	−·023	−·008	+·016	+·036	+·040	+·026	+·012	−·002	−·017	−·030	−·029	−·011	
June to August	−·004	+·010	+·023	+·039	+·038	+·020	+·004	−·011	−·027	−·041	−·041	−·028	−·011	+·004	+·019	+·032	+·033	+·021	+·008	−·004	−·017	−·029	−·029	−·014	

TABLE 93.
BOMBAY.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January -	−·004	+·023	+·049	+·069	+·067	+·049	+·018	−·014	−·037	−·049	−·050	−·048	−·031	−·011	+·008	+·023	+·023	+·012	+·002	−·008	−·020	−·029	−·029	−·021	630
February -	−·001	+·025	+·049	+·068	+·071	+·053	+·024	−·009	−·035	−·051	−·053	−·046	−·035	−·016	+·005	+·018	+·022	+·015	+·006	−·007	−·021	−·029	−·029	−·019	579
March - -	+·005	+·029	+·052	+·066	+·066	+·051	+·025	−·005	−·031	−·050	−·054	−·050	−·039	−·022	−·002	+·015	+·020	+·015	+·006	−·008	−·021	−·028	−·027	−·015	614
April - -	+·010	+·032	+·053	+·063	+·059	+·047	+·026	−·001	−·027	−·046	−·055	−·053	−·040	−·026	−·006	+·010	+·018	+·013	+·003	−·007	−·020	−·026	−·023	−·010	609
May - -	+·010	+·031	+·046	+·055	+·053	+·043	+·027	+·002	−·019	−·038	−·049	−·046	−·034	−·020	−·004	+·010	+·018	+·013	+·003	−·011	−·022	−·026	−·021	−·010	629
June - -	·000	+·016	+·030	+·039	+·039	+·033	+·022	+·007	−·011	−·027	−·037	−·036	−·025	−·011	+·005	+·018	+·026	+·021	+·008	−·008	−·022	−·030	−·027	−·019	645
July - -	−·007	+·006	+·023	+·031	+·034	+·029	+·020	+·008	−·006	−·020	−·030	−·028	−·019	−·006	+·007	+·018	+·025	+·018	+·006	−·009	−·023	−·030	−·030	−·024	666
August -	−·007	+·010	+·028	+·038	+·041	+·035	+·021	+·003	−·013	−·027	−·035	−·030	−·019	−·006	+·008	+·021	+·026	+·019	+·005	−·012	−·025	−·032	−·031	−·023	653
September -	−·003	+·020	+·040	+·050	+·049	+·040	+·020	−·004	−·025	−·039	−·043	−·036	−·023	−·006	+·011	+·025	+·026	+·018	+·004	−·011	−·024	−·031	−·029	−·018	644
October -	+·010	+·032	+·051	+·062	+·058	+·037	+·009	−·017	−·040	−·051	−·050	−·039	−·026	−·005	+·014	+·022	+·021	+·012	−·001	−·014	−·023	−·027	−·023	−·012	659
November -	+·009	+·033	+·055	+·069	+·062	+·041	+·009	−·021	−·041	−·051	−·050	−·039	−·025	−·004	+·013	+·021	+·020	+·009	−·001	−·014	−·025	−·030	−·026	−·013	640
December -	−·001	+·026	+·052	+·068	+·065	+·045	+·014	−·018	−·039	−·050	−·051	−·041	−·028	−·007	+·011	+·021	+·022	+·012	+·001	−·010	−·021	−·029	−·028	−·018	641
Year - -	+·002	+·023	+·044	+·056	+·055	+·042	+·019	−·006	−·027	−·042	−·046	−·041	−·029	−·012	+·006	+·018	+·022	+·014	+·003	−·010	−·022	−·029	−·027	−·017	
June to August	−·005	+·011	+·027	+·036	+·038	+·032	+·021	+·006	−·010	−·025	−·034	−·031	−·021	−·008	+·007	+·019	+·026	+·019	+·006	−·010	−·023	−·031	−·029	−·022	

TABLE 94.
DEESA.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January - -	+·017	+·035	+·050	+·066	+·073	+·059	+·030	−·004	−·028	−·042	−·044	−·042	−·032	−·018	−·004	+·004	+·009	+·004	−·005	−·011	−·022	−·028	−·034	−·023	13
February -	+·007	+·027	+·047	+·066	+·072	+·061	+·040	+·005	−·021	−·040	−·047	−·045	−·033	−·023	−·007	+·005	+·009	+·004	−·003	−·013	−·023	−·031	−·031	−·020	13
March - -	+·011	+·026	+·049	+·060	+·061	+·052	+·034	+·003	−·022	−·040	−·050	−·046	−·038	−·025	−·011	+·002	+·009	+·009	+·005	−·005	−·015	−·026	−·028	−·016	13
April - -	+·024	+·044	+·053	+·069	+·068	+·055	+·037	+·009	−·021	−·044	−·059	−·065	−·054	−·041	−·027	−·011	+·001	+·002	+·001	−·006	−·013	−·016	−·011	·000	14
May - -	+·038	+·056	+·064	+·067	+·062	+·051	+·035	+·012	−·014	−·038	−·061	−·063	−·059	−·050	−·036	−·022	−·010	−·007	−·005	−·007	−·008	−·009	−·004	+·010	13
June - -	+·023	+·032	+·042	+·046	+·046	+·035	+·023	+·003	−·017	−·038	−·056	−·060	−·054	−·044	−·024	−·004	+·014	+·016	+·013	+·006	+·001	−·003	−·003	+·011	14
July - -	+·005	+·017	+·026	+·033	+·034	+·028	+·021	+·007	−·008	−·030	−·042	−·045	−·040	−·034	−·020	−·002	+·013	+·016	+·014	+·012	−·001	−·005	−·003	·000	15
August - -	+·006	+·021	+·034	+·042	+·044	+·037	+·025	+·004	−·015	−·033	−·045	−·046	−·042	−·026	−·012	+·003	+·015	+·015	+·010	+·001	−·011	−·015	−·015	·000	15
September -	+·006	+·023	+·042	+·049	+·048	+·037	+·020	−·008	−·032	−·051	−·058	−·051	−·042	−·027	−·007	+·009	+·015	+·016	+·012	+·003	−·001	−·005	−·002	−·006	14
October - -	·000	+·025	+·046	+·058	+·057	+·043	+·020	−·013	−·034	−·045	−·050	−·041	−·028	−·016	·000	+·008	+·013	+·009	+·006	−·004	−·013	−·017	−·013	−·004	10
November -	+·007	+·021	+·044	+·058	+·057	+·044	+·030	−·005	−·025	−·045	−·047	−·042	−·030	−·014	+·001	+·013	+·017	+·012	+·002	−·009	−·019	−·024	−·025	−·019	13
December -	·000	+·018	+·038	+·058	+·059	+·045	+·018	−·012	−·032	−·042	−·042	−·031	−·020	−·006	+·007	+·014	+·018	+·011	−·001	−·013	−·020	−·027	−·024	−·014	13
Year - -	+·012	+·028	+·044	+·056	+·056	+·045	+·027	·000	−·023	−·041	−·050	−·048	−·040	−·027	−·012	+·001	+·010	+·009	+·004	−·004	−·012	−·017	−·016	−·006	
June to August	+·011	+·023	+·034	+·040	+·041	+·033	+·023	+·005	−·013	−·034	−·048	−·050	−·045	−·035	−·019	−·001	+·014	+·016	+·012	+·006	−·004	−·008	−·007	+·004	

TABLE 95.

KURRACHEE.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	+·023	+·034	+·047	+·060	+·064	+·045	+·016	−·013	−·033	−·044	−·045	−·040	−·030	−·018	−·002	+·007	+·013	+·001	−·003	−·009	−·018	−·022	−·025	−·022	16
February	+·026	+·034	+·045	+·055	+·060	+·047	+·019	−·008	−·029	−·042	−·047	−·043	−·032	−·018	·000	+·014	+·016	+·006	−·004	−·013	−·020	−·026	−·021	−·017	16
March	+·015	+·026	+·041	+·048	+·047	+·038	+·024	+·002	−·015	−·030	−·036	−·033	−·025	−·016	−·005	+·006	+·009	+·006	−·004	−·012	−·018	−·026	−·026	−·018	18
April	+·010	+·019	+·034	+·037	+·039	+·028	+·015	−·004	−·022	−·037	−·042	−·040	−·031	−·016	−·004	+·008	+·014	+·013	+·009	·000	−·008	−·014	−·012	−·006	17
May	+·018	+·029	+·036	+·043	+·042	+·033	+·017	+·005	−·012	−·029	−·031	−·038	−·030	−·023	−·007	+·007	+·009	+·006	−·002	−·011	−·018	−·022	−·015	−·007	17
June	+·011	+·032	+·029	+·031	+·027	+·021	+·012	+·001	−·009	−·019	−·031	−·032	−·028	−·019	−·009	+·003	+·011	+·008	+·003	−·002	−·007	−·012	−·012	−·009	17
July	+·016	+·019	+·023	+·026	+·026	+·020	+·012	−·002	−·008	−·023	−·028	−·030	−·027	−·017	+·003	+·015	+·017	+·011	+·005	·000	−·007	−·015	−·016	−·011	17
August	+·005	+·016	+·024	+·028	+·030	+·022	+·014	−·004	−·015	−·031	−·038	−·037	−·028	−·014	+·002	+·014	+·020	+·016	+·010	+·002	−·007	−·014	−·014	−·010	18
September	+·002	+·011	+·023	+·031	+·028	+·020	+·004	−·016	−·030	−·043	−·036	−·033	−·024	−·012	+·002	+·016	+·020	+·018	+·012	+·005	−·003	−·009	−·004	+·008	16
October	+·012	+·025	+·036	+·043	+·042	+·024	−·005	−·028	−·042	−·053	−·051	−·040	−·028	−·011	+·009	+·014	+·017	+·016	+·010	+·005	+·003	·000	+·002	+·011	15
November	+·032	+·041	+·050	+·057	+·051	+·033	+·005	−·019	−·040	−·053	−·048	−·037	−·027	−·013	+·001	+·011	+·013	+·008	+·002	−·005	−·014	−·020	−·021	−·018	15
December	+·021	+·030	+·042	+·052	+·055	+·034	+·009	−·018	−·041	−·048	−·049	−·040	−·031	−·016	+·003	+·014	+·018	+·012	+·003	−·002	−·008	−·014	−·012	−·004	16
Year	+·016	+·025	+·036	+·042	+·042	+·030	+·012	−·009	−·025	−·038	−·040	−·037	−·029	−·016	−·001	+·010	+·014	+·010	+·003	−·004	−·011	−·016	−·015	−·009	
June to August	+·011	+·019	+·025	+·028	+·028	+·021	+·013	−·002	−·011	−·024	−·032	−·033	−·028	−·017	−·001	+·011	+·016	+·012	+·006	·000	−·007	−·014	−·014	−·010	

For Bombay we have entered in Table 93 the inequalities derived from the whole of the hourly observations of the years 1844 and 1847 (June) to 1870, in preference to those derived from the observations of a single day only for each month. The day appointed for the hourly observations, under the system of observation at all the stations, was from 6 a.m. of the 21st to 5 a.m. of the 22nd day of the month, local mean time.

176. The curves of figures 308 to 372 have been constructed from the numbers in Tables 91 to 95, and represent the diurnal variations of barometric pressure at the several stations. We observe the same regularity that has been remarked upon in paragraph 36 with respect to the variation of Bombay in the double daily oscillation of the barometer at the four other stations, a regularity which appears as well in the curves of each individual month as in the mean curves for the year. The amplitudes of the day and night oscillations are, however, of very different magnitudes in different seasons, and both their relative and absolute values differ at different stations.

In the monsoon months (June to August) the amplitude of the day oscillation is less at all, and much less at the three southernmost stations, than on the average of the year; and as the night oscillations are not at all or but little less, the curves exhibit a strongly-marked equalization of the night and day movements in the monsoon months as compared with the rest of the year. Figures 320, 333, 346, 359, and 372 have been placed side by side with the yearly curves to show this equalization with respect to the average variations. The following table exhibits the amplitudes of the oscillations, in averages for the year and for the monsoon months.

TABLE 96.

AVERAGE DAY and NIGHT RANGES of BAROMETRIC PRESSURE, or the Ranges between the a.m. Maximum and p.m. Minimum, and between the p.m. Maximum and a.m. Minimum, for the whole Year, and for the Months June to August.

	Day.		Night.	
	Year.	June to August.	Year.	June to August.
	Inch.	Inch.	Inch.	Inch.
Belgaum	·097	·062	·041	·044
Poona	·117	·080	·070	·062
Bombay	·102	·072	·051	·057
Deesa	·106	·091	·027	·024
Kurrachee	·082	·061	·030	·030

At the three first stations the day range of the monsoon is only about two-thirds of the average of the year, and the night range is considerably larger than at the two northern stations. Comparing Bombay with Poona and Belgaum, we see that the absolute diurnal range is about as great on the Deccan plateau, at an elevation of 2,000 feet, as in the Konkan near the sea level, a fact which seems to associate this variation rather with the general ground level than with the mean sea level.

177. *Maxima and Minima.*—Table 97 shows for each month of the year the greatest and least values of barometric pressure observed at 9.30 a.m. or 3.30 p.m. at the several stations.

TABLE 97.

	January.			February.			March.			April.			May.			June.		
	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
Belgaum	27·624	27·192	·432	27·602	27·200	·402	27·534	27·185	·349	27·538	27·111	·427	27·466	27·082	·384	27·403	27·043	·360
Poona	28·263	27·769	·494	28·229	27·756	·473	28·096	27·695	·401	28·062	27·630	·432	28·005	27·492	·513	27·953	27·352	·601
Bombay	30·133	29·737	·396	30·142	29·741	·401	30·069	29·672	·397	30·046	29·614	·432	29·971	29·491	·480	29·905	29·385	·520
Deesa	29·955	29·292	·663	29·955	29·246	·709	29·822	29·178	·644	29·792	29·105	·687	29·665	29·039	·626	29·610	28·820	·790
Kurrachee	30·454	29·762	·692	30·373	29·791	·582	30·308	29·757	·551	30·217	29·567	·650	30·118	29·332	·786	29·976	29·322	·654

TABLE 97—*continued.*

	July.			August.			September.			October.			November.			December.		
	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
Belgaum	27·411	27·078	·333	27·426	27·104	·322	27·470	27·085	·385	27·518	27·085	·433	27·599	27·196	·403	27·650	27·202	·448
Poona	27·915	27·491	·424	27·957	27·578	·379	28·039	27·617	·422	28·086	27·614	·472	28·161	27·729	·432	28·180	27·749	·431
Bombay	29·862	29·465	·397	29·946	29·520	·426	29·978	29·483	·495	30·077	29·590	·487	30·142	29·674	·468	30·163	29·711	·452
Deesa	29·524	28·856	·668	29·644	28·947	·697	29·755	28·998	·757	29·867	29·098	·769	29·924	29·269	·655	29·961	29·309	·652
Kurrachee	29·898	29·319	·579	29·970	29·341	·629	30·098	29·521	·577	30·230	29·605	·625	30·327	29·813	·514	30·493	29·851	·642

The curves of figures 508 to 512, which have been constructed from the numbers in this table, show the extreme limits on the barometer scale beyond which the oscillations of barometric pressure in the respective months do not extend.

It will be noticed that whilst the lowest minima occur at all the stations, with a scarcely perceptible exception at Kurrachee, in June, the lowest maxima occur, with a scarcely perceptible exception at Belgaum, in July. Generally the movements both of the maxima and minima are similar to those of the mean barometric pressure, the largest values occurring about the winter solstice and the smallest values about the summer solstice, with gradual intermediate progressions.

Temperature of the Air.

178. *Mean temperature and secular variation.*—The mean temperature of the air for each year of complete observations is shown for the several stations in Table 98, the means being derived from the two daily observations made at the hours 9.30 a.m. and 3.30 p.m.

Table 98.

Year.	Belgaum.		Poona.		Bombay.		Deesa.		Kurrachee.	
	Mean Temperature.	Excess above General Mean.	Mean Temperature.	Excess above General Mean.	Mean Temperature.	Excess above General Mean.	Mean Temperature.	Excess above General Mean.	Mean Temperature.	Excess above General Mean.
1856	76·8	−0·9	80·1	+0·6	83·8	+0·9			80·4	−0·2
1857	76·1	−1·6	79·1	−0·4	83·2	+0·3	85·1	−0·7	80·1	−0·5
1858	76·8	−0·9			83·4	+0·5	86·4	+0·6	80·0	−0·6
1859	78·6	+0·9	80·3	+0·8	83·4	+0·5	86·6	+0·8	80·7	+0·1
1860	77·9	+0·2	79·6	+0·1	83·0	+0·1			80·4	−0·2
1861	77·9	+0·2	78·5	−1·0	82·4	−0·5	84·0	−1·8	79·9	−0·7
1862	78·0	+0·3	79·0	−0·5	83·7	+0·8	84·8	−1·0	81·1	+0·5
1863			78·7	−0·8	83·0	+0·1	84·8	−1·0	80·9	+0·3
1864	77·7	0·0	78·7	−0·8	83·2	+0·3	85·8	0·0	80·6	0·0
1865	78·0	+0·3	79·8	+0·3	84·2	+1·3	87·2	+1·4	81·8	+1·2
1866	78·2	+0·5	80·0	+0·5	81·4	−1·5	86·5	+0·7	80·1	−0·5
1867	77·3	−0·4	79·6	+0·1	81·8	−1·1				
1868	78·4	+0·7	80·3	+0·8	82·2	−0·7				
1869	78·7	+1·0	80·5	+1·0	83·0	+0·1	85·8	0·0	87·5	
1870	77·3	−0·4	79·2	−0·3	82·2	−0·7	85·3	−0·5	85·0	
181	77·6	−0·1	79·9	+0·4	83·3	+0·4	85·6	−0·2	82·2	
1872	78·2	+0·5	80·2	+0·7	82·1	−0·8	85·7	−0·1		
General Means-	77·7		79·5		82·9		85·8		80·6	
Additional Years - 1873	77·7	0·0	79·7	+0·2	81·8	−1·1	86·6	+0·8	83·0	
Additional Years - 1874	77·0	−0·7	78·8	−0·7	81·3	−1·6	85·6	−0·2	81·7	

In figures 258 to 262, which represent the numbers in this table, we observe a fair degree of correspondence in the temperature movements at Belgaum and Poona, the two Deccan stations, throughout the period of 17 years; also at Deesa and Kurrachee from 1861

to 1866. The observations at Kurrachee were stopped from October 1867 to February 1868, and when resumed there is an evident change either in the air thermometer or the manner of using it, probably in the mode of exposure, for the years 1868 to 1870 show mean monthly, and consequently mean annual temperatures, extravagantly larger than those observed in preceding years. The general mean refers to the years 1856 to 1867, and the excesses are shown for those years only. The break in the curve for Bombay, between 1865 and 1866, is made in consequence of the removal of the thermometers at the beginning of 1866 from their own revolving stand into the new cage in the thermometer shed.

179. *Annual variation.*—Table 99 shows for each station and each month of the year the excesses of the mean monthly temperatures above the mean annual temperature; first, as deduced from the observations taken daily at the hours 9.30 a.m. and 3.30 p.m.; and secondly, after correction for the diurnal inequality at those hours.

TABLE 99.

		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
From Observations at 9.30 a.m. and 3.30 p.m.	Belgaum	− 2·1	+2·1	+6·1	+8·2	+ 5·8	− 1·5	−4·8	−5·0	−3·3	−1·0	−1·6	− 2·9
	Poona	− 5·0	−1·3	+4·1	+9·1	+ 8·1	+ 1·6	−2·5	−3·7	−2·6	−0·3	−2·4	− 5·1
	Bombay	− 5·2	−3·5	−0·3	+3·5	+ 5·8	+ 3·1	0·0	−1·1	−0·3	+1·3	−0·2	− 3·1
	Deesa	−12·7	−7·1	+0·2	+9·2	+11·5	+ 8·9	+1·8	−2·2	−0·1	+2·3	−2·8	− 9·3
	Kurrachee	−12·0	−7·9	−2·3	+3·5	+ 5·7	+ 8·0	+5·8	+2·7	+3·0	+3·1	−1·3	− 8·8
Corrected for Diurnal Inequality.	Belgaum	− 2·9	+0·4	+3·8	+6·4	+ 4·7	+ 0·4	−2·4	−3·3	−2·2	−0·3	−1·5	− 3·2
	Poona	− 5·4	−1·8	+3·4	+7·8	+ 6·9	+ 2·1	−1·3	−2·4	−1·8	−0·2	−2·2	− 5·1
	Bombay	− 5·6	−4·8	−1·3	+2·2	+ 5·0	+ 4·1	+1·2	+0·4	+0·5	+1·3	−0·6	− 2·8
	Deesa	−14·2	−8·9	−1·7	+8·9	+12·7	+11·2	+5·9	+1·8	+1·8	−0·1	−6·1	−11·2
	Kurrachee	−12·7	−9·3	−2·3	+3·5	+ 6·7	+ 9·7	+8·4	+5·1	+4·8	+1·2	−4·5	−10·0

The corrections are found from the diurnal inequalities at the several hours in each month, as given in Tables 100 to 104, paragraph 185. They are the means of these inequalities for the hours 9 a.m. and 10 a.m. and 3 p.m. and 4 p.m., and are applied subtractively. For Bombay, instead of corrected inequalities, we have entered in the second part of Table 99 the inequalities found from the hourly observations of the years 1866 to 1872 (see Table 16).

180. The numbers in Table 99 are curved in figures 278 to 282, the uncorrected inequalities in black ink, and the corrected inequalities in red ink. The latter curves represent the annual variations of temperature at the several stations, with as close an approximation as observations at 9.30 a.m. and 3.30 p.m. are capable of exhibiting them. The differences between these and the uncorrected (black) curves are at every station very considerable; and it speaks of a matured judgment in the designers of this system of observation, that from the first the necessity was foreseen of supplementing the daily observations by a certain number of hourly observations, taken at convenient intervals, that should in the course of a series of years accumulate to a sufficient body to allow of a satisfactory determination of the diurnal variation. Confining our notice to the red curves,

we see that the annual variation of temperature has a minimum value at Belgaum and Poona very near the beginning of the year, and at the three stations of lower level in January. There is a continuous fall towards this minimum at Belgaum, Poona, and Bombay from October, and at Deesa and Kurrachee from near the 1st September. On the other hand, a rise of temperature follows it at Belgaum and Poona till April, at Bombay and Deesa till May, and at Kurrachee till June, the several months named being those of maximum temperature of the year at the respective stations.

181. The continuation of this rise, which would as a rule be looked for in the northern hemisphere till after the summer solstice, is prevented by the arrival of the south-west monsoon, which both by its heavy rains from cool regions aloft, by the thick cloudiness which accompanies it, and by its strong winds from over the relatively cool ocean, tempers what would otherwise be the summer heat of the stations to a remarkable extent.

182. The order in which the monsoon arrives at the several stations, as marked by the commencement of a depression in these curves, is clearly first at Belgaum, next at Poona, then at Bombay, following very soon at Deesa, and finally at Kurrachee, the most southerly station experiencing it first, and the others in the order of their latitudes. During the wane of the monsoon, which at Bombay ceases about the beginning of October, the temperature rises at the three most southerly stations—Belgaum, Poona, and Bombay—till October, when a secondary maximum occurs; but at Deesa and Kurrachee there is no rise of temperature from August to September, but only an interruption of the preceding and following fall. We thus see that at the five stations there is a proper winter season at the time when the sun has its largest south declination, and when its radiation is therefore least effective to heat the Indian peninsula; but, by reason of the monsoon, there is no fully developed summer season at the time of the summer solstice: the nearest approach to such a season is made at the most northern station, Kurrachee, which lies without the tropics.

183. The extent of the rise, from the least winter monthly mean to the greatest monthly mean, is greatest (26°·9) at Deesa; it is 22°·4 at Kurrachee, 13°·2 at Poona, 10°·6 at Bombay, and 9°·6 at Belgaum.

These numbers, although showing a general increase with increase of latitude, are evidently not wholly explained by a variation with that element of position only; for with respect to such a variation the ranges at the inland stations—Belgaum, Poona, and Deesa—are relatively to the ranges at Bombay and Kurrachee too large. The following reason may be given why a coast station should have a more contracted annual and diurnal range of temperature than a station inland in the same latitude: the winds from seaward—and especially if these be the prevalent winds—tend to communicate to the coast the temperature which prevails over the ocean; and this, it is well known, is more equable, both as to seasonal and diurnal changes, than the temperature over land; thus the oscillations of temperature at a coast station, being those of a land station largely modified by sea air, will be of range intermediate between those of an inland station and those of the open sea.

The principal reason why the temperature range at sea is less than on land is that the water of the ocean is a much worse absorber—and therefore radiator—than the ground surface of the land; it therefore absorbs much less of the sun's heat than the soil does, and conversely gives off less into space and the surrounding atmosphere; but there is also a further reason in that at sea a greater proportion than on land of the sun's heat received is consumed in producing evaporation, and such heat being otherwise disposed of, is therefore unavailable to increase the temperature of the surface water.

184. As the principal causes of the annual variations of temperature at the five stations, we have therefore the variation, with his position in declination, of the sun's effective radiation: this, if unaffected by other causes, would give rise to the common succession of seasons; then we have a variation of the same effective radiation due to the latitude of the place, being greatest for the highest latitude; next we have nearness of the station to the sea, diminishing the range of the seasonal variation; and finally we have the monsoon interrupting the regular course of the seasons, and preventing the occurrence of a summer season proper.

185. *Diurnal variation.*—In Tables 100 to 104 are shown, for the several stations, and for each month, the quarter June to August, and the whole year, the excesses of the mean temperatures at the several hours of the day above the mean temperature of the 24 hours; also the number of complete days' observations, being generally not more than one in each month of each year, from which the means are derived.

TABLE 100.

BELGAUM.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	−8·2	−7·3	−4·6	−1·2	+2·0	+4·4	+6·3	+ 7·9	+ 9·0	+ 9·6	+9·1	+7·8	+5·1	+3·3	+0·6	−1·0	−2·1	−3·7	−4·1	−5·4	−6·1	−6·7	−6·9	−7·6	16
February	−9·3	−7·9	−4·0	0·0	+3·2	+5·8	+7·6	+ 9·2	+10·4	+10·2	+9·6	+8·1	+5·9	+2·3	+0·4	−1·7	−2·6	−3·9	−5·3	−6·1	−6·8	−7·4	−8·2	−8·3	17
March	−8·3	−6·6	−3·1	+0·7	+4·0	+6·7	+8·6	+10·1	+11·1	+10·9	+9·8	+7·7	+4·0	+0·8	−1·6	−2·9	−4·0	−5·0	−5·7	−6·5	−7·0	−7·9	−8·3	−8·6	17
April	−7·8	−5·6	−2·3	+0·5	+4·8	+7·2	+9·3	+10·8	+11·4	+10·4	+8·1	+5·0	+2·3	+0·3	−1·5	−2·6	−3·6	−4·2	−5·2	−6·0	−6·7	−7·5	−8·1	−8·	17
May	−6·0	−4·3	−2·1	+0·4	+2·8	+5·4	+7·8	+ 9·2	+10·0	+ 9·3	+7·8	+5·1	+1·9	−0·2	−1·5	−2·5	−3·4	−4·4	−4·9	−5·2	−5·7	−6·0	−6·5	−6·8	17
June	−2·4	−1·3	−0·3	+0·9	+2·1	+2·9	+3·5	+ 4·2	+ 3·8	+ 3·0	+2·3	+1·6	+0·4	−0·5	−0·9	−1·2	−1·6	−1·9	−2·2	−2·2	−2·5	−2·8	−2·8	−2·7	17
July	−1·8	−1·1	0·0	+0·8	+1·6	+2·2	+2·3	+ 2·8	+ 3·0	+ 2·4	+1·8	+1·3	+0·3	−0·2	−0·6	−0·9	−1·2	−1·4	−1·5	−1·5	−1·7	−1·8	−1·8	−1·9	17
August	−2·7	−2·0	−0·7	+0·8	+2·1	+3·0	+3·9	+ 4·3	+ 4·2	+ 3·7	+3·0	+1·9	+0·6	−0·4	−1·1	−1·4	−1·8	−2·0	−2·3	−2·4	−2·7	−2·8	−2·9	−3·1	16
September	−3·5	−2·5	−1·0	+0·6	+2·5	+4·1	+5·3	+ 5·7	+ 5·4	+ 5·0	+4·0	+2·3	+0·7	−0·2	−1·0	−1·6	−2·1	−2·5	−2·7	−3·2	−3·2	−3·5	−3·6	−3·9	16
October	−4·4	−3·5	−1·9	−0·2	+1·9	+3·7	+4·7	+ 5·5	+ 5·9	+ 6·0	+5·6	+4·3	+2·1	+0·3	−0·3	−1·1	−1·6	−2·4	−2·8	−3·5	−3·9	−4·4	−5·0	−5·1	16
November	−6·7	−5·3	−3·4	−0·2	+2·2	+4·1	+5·5	+ 6·4	+ 7·4	+ 7·4	+6·7	+5·7	+3·6	+2·0	+0·6	−0·9	−1·9	−2·6	−3·6	−4·5	−5·0	−5·4	−5·8	−6·3	13
December	−7·2	−6·4	−4·0	−0·6	+2·2	+4·1	+5·8	+ 6·9	+ 7·9	+ 8·1	+7·7	+6·4	+4·2	+2·2	+0·3	−0·7	−1·7	−2·5	−3·3	−4·2	−5·0	−5·7	−6·5	−7·0	13
June to August	−2·3	−1·5	−0·3	+0·8	+1·9	+2·7	+3·2	+ 3·8	+ 3·7	+ 3·0	+2·4	+1·6	+0·4	−0·4	−0·9	−1·2	−1·5	−1·8	−2·0	−2·0	−2·3	−2·5	−2·5	−2·6	
Year	−5·7	−4·5	−2·3	+0·2	+2·6	+4·5	+5·9	+ 6·9	+ 7·5	+ 7·2	+6·3	+4·8	+2·6	+0·9	−0·5	−1·5	−2·3	−3·0	−3·6	−4·2	−4·7	−5·1	−5·5	−5·8	

Table 101.

POONA.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	−7·6	−7·1	−6·1	−3·9	−1·0	+2·1	+4·7	+6·9	+8·1	+8·7	+8·3	+7·3	+5·6	+3·9	+2·8	+1·6	+0·2	−0·7	−2·0	−3·0	−4·3	−6·7	−8·0	−8·1	20
February	−8·7	−8·3	−7·3	−4·1	−0·7	+2·5	+4·6	+6·5	+8·2	+8·6	+8·6	+8·0	+6·4	+4·3	+2·5	+1·3	+0·2	−0·8	−2·0	−3·6	−4·9	−6·4	−7·3	−7·8	20
March	−8·2	−7·7	−6·2	−3·5	−0·2	+2·8	+5·1	+7·3	+8·9	+8·8	+8·5	+7·5	+6·0	+4·1	+2·3	+0·5	−0·6	−1·9	−3·1	−3·9	−4·7	−5·9	−7·1	−7·7	21
April	−7·7	−6·5	−4·3	−1·9	+1·1	+3·8	+6·2	+7·9	+8·7	+8·9	+8·0	+6·5	+4·5	+2·1	+0·4	−0·5	−1·3	−2·3	−3·3	−4·4	−5·1	−6·0	−7·2	−7·5	21
May	−6·6	−5·6	−3·9	−1·6	+1·7	+3·7	+5·7	+7·3	+7·8	+7·9	+7·3	+6·1	+3·6	+1·5	+0·7	−1·0	−1·6	−2·4	−3·3	−4·2	−4·8	−5·7	−6·5	−6·7	21
June	−2·3	−1·6	−0·8	+0·4	+1·8	+2·7	+3·5	+3·8	+4·1	+3·6	+2·8	+2·1	+0·8	+0·1	−0·7	−1·2	−1·3	−1·6	−1·9	−2·0	−2·6	−2·8	−2·9	−3·2	20
July	−1·6	−1·4	−0·5	+0·2	+1·2	+2·0	+2·7	+2·7	+2·7	+2·6	+2·0	+1·1	+0·5	0·0	−0·5	−0·8	−0·9	−1·2	−1·3	−1·4	−1·6	−1·7	−1·9	−1·8	21
August	−2·1	−1·7	−1·1	−0·3	+0·6	+1·4	+2·2	+2·7	+3·1	+3·0	+2·3	+1·7	+0·7	+0·3	−0·1	−0·3	−0·5	−0·7	−1·0	−1·3	−1·6	−2·1	−2·2	−2·1	21
September	−3·2	−2·5	−1·7	−0·4	+1·1	+2·2	+3·2	+4·1	+4·0	+3·6	+3·2	+2·3	+1·3	+0·4	−0·2	−0·6	−0·9	−1·3	−1·7	−2·2	−2·5	−2·9	−2·9	−2·8	20
October	−5·7	−5·3	−4·0	−1·6	+0·7	+2·6	+4·2	+5·5	+6·0	+6·0	+5·5	+4·4	+3·0	+2·0	+1·1	+0·3	−0·5	−1·3	−2·0	−2·8	−3·7	−4·4	−4·7	−4·8	20
November	−7·2	−7·1	−5·4	−2·8	0·0	+2·8	+5·0	+5·9	+6·9	+6·7	+6·3	+5·5	+4·3	+3·3	+2·0	+0·8	+0·1	−0·7	−1·4	−2·5	−3·9	−5·1	−6·1	−6·5	18
December	−7·8	−7·4	−6·2	−3·3	−0·6	+2·6	+4·9	+6·4	+7·1	+7·5	+7·4	+6·7	+5·3	+4·3	+2·9	+1·8	+0·8	−0·2	−1·8	−3·2	−4·9	−6·6	−7·4	−7·9	20
June to August	−2·0	−1·6	−0·8	+0·1	+1·2	+2·0	+2·8	+3·1	+3·3	+3·1	+2·4	+1·3	+0·7	+0·1	−0·4	−0·8	−0·9	−1·2	−1·4	−1·6	−1·9	−2·2	−2·3	−2·4	
Year	−5·8	−5·2	−4·0	−2·0	+0·4	+2·5	+4·3	+5·5	+6·2	+6·3	+5·8	+4·9	+3·4	+2·1	+1·0	+0·1	−0·6	−1·3	−2·1	−2·9	−3·8	−4·7	−5·4	−5·6	

Table 102.

BOMBAY.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	−5·2	−5·2	−3·2	−0·9	+1·2	+3·1	+5·1	+6·4	+7·0	+7·0	+6·3	+3·8	+1·9	+0·9	+0·3	−0·5	−1·4	−2·3	−2·8	−3·2	−3·7	−4·1	−4·5	−4·9	180
February	−5·5	−5·3	−2·9	−0·7	+1·5	+3·6	+5·2	+6·2	+6·7	+6·7	+6·2	+4·5	+1·8	+0·6	0·0	−0·7	−1·6	−2·3	−3·0	−3·4	−3·8	−4·4	−4·7	−5·1	164
March	−5·0	−4·2	−1·7	+0·4	+2·1	+3·4	+4·5	+5·3	+5·6	+5·5	+4·9	+3·7	+1·3	+0·1	−0·4	−1·0	−1·5	−2·2	−2·6	−2·9	−3·2	−3·6	−4·1	−4·5	175
April	−4·5	−2·7	−0·6	+1·1	+2·2	+3·3	+4·4	+5·0	+5·3	+5·1	+4·4	+3·2	+0·9	−0·3	−0·9	−1·4	−1·8	−2·1	−2·5	−2·8	−3·2	−3·6	−4·0	−4·4	176
May	−3·6	−1·9	−0·3	+0·9	+2·0	+3·1	+3·9	+4·6	+4·9	+4·7	+4·0	+2·8	+0·9	−0·6	−1·2	−1·6	−1·9	−2·1	−2·5	−2·8	−3·1	−3·3	−3·6	−3·7	179
June	−2·2	−1·5	−0·5	+0·5	+1·5	+2·1	+2·7	+3·2	+3·3	+3·2	+2·7	+1·7	+0·5	−0·3	−0·7	−1·0	−1·2	−1·3	−1·4	−1·6	−1·9	−2·0	−2·2	−2·4	180
July	−1·6	−1·1	−0·4	+0·3	+0·9	+1·5	+2·0	+2·4	+2·2	+2·0	+1·6	+0·7	0·0	−0·4	−0·6	−0·8	−0·9	−0·9	−0·9	−1·2	−1·2	−1·4	−1·5	−1·6	186
August	−1·8	−1·4	−0·6	+0·2	+1·0	+1·7	+2·2	+2·5	+2·6	+2·3	+1·8	+1·0	+0·1	−0·4	−0·6	−0·7	−0·9	−1·0	−1·0	−1·2	−1·4	−1·6	−1·7	−1·8	181
September	−2·4	−1·9	−0·9	+0·2	+1·0	+2·0	+2·7	+3·3	+3·5	+3·4	+3·0	+1·8	+0·4	−0·2	−0·5	−0·9	−1·1	−1·3	−1·5	−1·8	−1·9	−2·1	−2·3	−2·3	179
October	−4·0	−3·0	−1·4	−0·1	+1·2	+2·6	+4·1	+4·9	+5·4	+5·4	+4·7	+2·8	+1·0	+0·1	−0·5	−1·1	−1·7	−2·2	−2·4	−2·7	−3·0	−3·2	−3·5	−3·8	182
November	−4·9	−4·0	−2·1	−0·4	+1·4	+3·2	+5·1	+6·4	+6·9	+6·6	+5·5	+2·8	+1·3	+0·4	−0·3	−1·1	−2·2	−2·6	−2·9	−3·3	−3·7	−4·0	−4·3	−4·6	178
December	−4·8	−4·5	−2·7	−0·9	+0·8	+2·5	+4·5	+6·1	+6·8	+6·8	+5·9	+3·2	+1·6	+0·8	+0·1	−0·7	−1·8	−2·4	−2·7	−3·1	−3·4	−3·8	−4·1	−4·4	179
June to August	−1·9	−1·3	−0·5	+0·3	+1·1	+1·8	+2·3	+2·7	+2·7	+2·5	+2·0	+1·1	+0·2	−0·4	−0·6	−0·8	−1·0	−1·1	−1·1	−1·3	−1·5	−1·7	−1·8	−1·9	
Year	−3·8	−3·1	−1·5	0·0	+1·4	+2·6	+3·8	+4·7	+5·0	+4·9	+4·2	+2·6	+0·9	0·0	−0·5	−1·0	−1·5	−1·9	−2·2	−2·5	−2·8	−3·1	−3·4	−3·7	

Table 103.

DEESA.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	−13·1	−12·8	−8·8	−1·4	+4·6	+ 8·8	+12·0	+13·3	+14·2	+14·4	+13·3	+10·6	+7·0	+3·8	+1·1	−1·3	−3·3	−5·0	−6·5	−7·8	− 9·1	−10·2	−11·5	−12·4	15
February	−15·9	−15·3	−9·4	−2·1	+4·8	+ 9·2	+11·9	+13·4	+14·2	+14·6	+14·1	+12·3	+8·9	+5·2	+2·1	−0·1	−2·2	−3·0	−6·0	−8·3	−10·0	−11·4	−12·6	−13·4	14
March	−14·4	−13·1	−6·8	+0·1	+4·6	+ 8·1	+10·9	+12·8	+13·5	+13·9	+13·1	+11·5	+8·4	+4·9	+2·3	−0·2	−2·4	−4·2	−6·2	−7·9	−10·0	−11·7	−12·9	−14·2	13
April	−15·1	−11·6	−5·9	−1·8	+2·5	+ 5·9	+ 8·8	+10·8	+12·1	+12·7	+12·1	+10·8	+8·2	+4·8	+2·2	+0·6	−0·9	−2·6	−4·1	−6·3	− 8·5	−10·1	−11·9	−13·1	13
May	−11·6	− 9·6	−6·9	−3·6	0·0	+ 3·6	+ 6·9	+ 9·3	+10·9	+11·7	+11·5	+10·5	+8·7	+5·8	+3·4	+1·2	−0·6	−2·6	−4·4	−6·0	− 7·4	− 8·8	− 9·9	−11·0	16
June	− 6·2	− 4·9	−3·0	−1·3	+0·3	+ 2·8	+ 4·5	+ 6·3	+ 7·2	+ 8·0	+ 7·8	+ 6·7	+5·0	+2·6	+1·7	−0·6	−1·7	−2·8	−3·7	−4·5	− 5·3	− 5·9	− 6·3	− 7·0	16
July	− 4·1	− 3·3	−2·0	−0·8	+0·7	+ 1·8	+ 2·5	+ 3·2	+ 4·2	+ 4·1	+ 4·4	+ 3·5	+2·7	+1·7	+0·9	0·0	−0·6	−1·4	−1·8	−2·3	− 2·8	− 3·3	− 3·5	− 3·8	16
August	− 4·0	− 3·4	−2·1	−1·0	+0·6	+ 2·0	+ 2·7	+ 3·8	+ 4·2	+ 4·3	+ 4·2	+ 3·5	+2·4	+1·5	+0·6	−0·2	−0·8	−1·3	−1·7	−2·1	− 2·6	− 3·0	− 3·5	− 3·9	17
September	− 7·1	− 6·1	−3·2	−0·6	+2·0	+ 3·9	+ 5·4	+ 6·8	+ 7·4	+ 7·9	+ 7·4	+ 6·0	+4·0	+2·2	+0·7	−0·5	−1·5	−2·6	−3·3	−4·3	− 5·1	− 5·9	− 6·4	− 7·0	15
October	−12·5	−10·6	−4·5	+2·0	+6·8	+10·0	+12·2	+13·6	+13·9	+13·6	+12·7	+10·1	+6·1	+3·3	+0·1	−1·9	−4·4	−6·5	−8·2	−9·7	−10·4	−11·7	−12·9	−14·1	13
November	−13·2	−12·5	−6·5	+2·4	+7·9	+11·9	+13·5	+14·6	+14·8	+14·6	+12·9	+ 9·9	+6·1	+2·6	0·0	−2·2	−4·0	−6·3	−7·7	−9·4	−10·7	−11·9	−13·1	−13·7	15
December	−12·8	−12·4	−8·5	−1·0	+6·0	+10·0	+12·3	+13·8	+14·4	+14·1	+12·9	+10·1	+6·0	+2·7	−0·1	−2·4	−3·7	−5·2	−6·6	−8·2	− 9·0	− 9·8	−10·4	−12·2	14
June to August	− 4·8	− 3·9	−2·4	−1·0	+0·5	+ 2·2	+ 3·2	+ 4·4	+ 5·2	+ 5·5	+ 5·5	+ 4·6	+3·4	+1·9	+1·1	−0·3	−1·0	−1·8	−2·4	−3·0	− 3·6	− 4·1	− 4·4	− 4·9	
Year	−10·8	− 9·6	−5·6	−0·7	+3·4	+ 6·5	+ 8·6	+10·2	+10·9	+11·2	+10·5	+ 8·8	+6·1	+3·4	+1·3	−0·6	−2·2	−3·8	−5·0	−6·4	− 7·6	− 8·6	− 9·5	−10·5	

Table 104.

KURRACHEE.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
January	− 9·6	− 9·1	−7·1	−1·5	+3·6	+5·8	+ 8·1	+ 9·0	+10·2	+10·1	+ 9·9	+7·6	+5·0	+2·6	+0·6	−1·1	−2·3	−3·3	−4·1	−5·1	−6·0	− 7·3	− 7·9	− 8·6	16
February	−10·3	− 9·4	−4·2	+0·1	+4·5	+7·1	+ 9·2	+10·2	+10·5	+10·4	+ 9·8	+8·3	+4·7	+1·6	0·0	−1·5	−3·2	−4·5	−5·2	−5·6	−6·5	− 7·8	− 8·7	− 9·5	16
March	− 8·6	− 6·9	−3·1	+0·9	+4·8	+6·8	+ 7·7	+ 7·8	+ 7·3	+ 6·9	+ 6·5	+5·1	+2·8	+1·2	−0·2	−1·1	−1·8	−2·7	−3·7	−4·5	−5·2	− 6·0	− 6·7	− 7·6	18
April	− 6·0	− 3·3	−0·3	+2·4	+4·9	+6·5	+ 7·8	+ 8·1	+ 7·7	+ 6·7	+ 5·4	+4·0	+1·6	−0·4	−1·7	−2·4	−3·0	−3·6	−4·2	−4·8	−5·4	− 5·8	− 6·4	− 6·9	17
May	− 4·0	− 2·0	0·0	+2·1	+3·4	+4·6	+ 5·2	+ 5·5	+ 5·6	+ 5·3	+ 4·5	+3·2	+1·6	−0·3	−1·3	−1·8	−2·5	−2·8	−3·2	−3·6	−4·0	− 4·5	− 4·9	− 5·0	17
June	− 3·4	− 1·6	0·0	+1·4	+3·5	+4·0	+ 4·5	+ 4·6	+ 4·6	+ 4·2	+ 3·3	+2·3	+1·0	−0·4	−1·2	−1·6	−2·0	−2·8	−2·9	−3·2	−3·3	− 3·4	− 3·7	− 4·1	17
July	− 2·2	− 1·3	−0·2	+1·2	+2·1	+2·8	+ 3·9	+ 4·1	+ 3·6	+ 3·1	+ 2·3	+1·4	+0·5	−0·3	−1·1	−1·3	−1·5	−1·7	−2·2	−2·5	−2·5	− 2·5	− 2·3	− 2·6	17
August	− 2·9	− 2·2	−0·9	+0·4	+2·0	+2·7	+ 3·6	+ 4·2	+ 4·2	+ 4·0	+ 3·1	+1·7	+0·7	−0·6	−1·0	−1·2	−1·4	−1·7	−2·1	−2·3	−2·3	− 2·4	− 2·7	− 2·7	18
September	− 3·9	− 2·9	−0·5	+0·9	+3·1	+4·1	+ 4·9	+ 5·0	+ 5·0	+ 4·6	+ 3·6	+2·2	+0·5	−0·4	−1·1	−1·4	−1·8	−2·1	−2·3	−2·6	−3·0	− 3·3	− 3·6	− 4·0	17
October	−10·2	− 8·3	−4·1	+0·8	+4·9	+8·2	+10·1	+11·2	+11·7	+11·0	+10·0	+7·1	+3·5	+1·0	−0·6	−1·9	−3·1	−4·2	−5·5	−6·4	−7·9	− 8·7	− 9·5	−10·0	15
November	−12·1	− 9·4	−4·3	+2·0	+6·8	+9·4	+11·6	+12·2	+12·5	+12·2	+11·0	+7·8	+4·4	+1·8	+0·2	−1·6	−3·1	−4·7	−6·3	−7·8	−8·9	−10·1	−10·7	−11·7	16
December	−10·6	−10·2	−7·3	−0·6	+4·3	+6·9	+ 8·8	+10·2	+10·6	+10·5	+ 9·8	+7·9	+4·6	+2·2	+0·7	−0·8	−2·2	−3·5	−5·0	−5·5	−6·6	− 7·6	− 7·9	− 8·8	16
June to August	− 2·8	− 1·7	−0·4	+1·0	+2·5	+3·2	+ 4·0	+ 4·3	+ 4·1	+ 3·8	+ 2·9	+1·8	+0·7	−0·4	−1·1	−1·4	−1·6	−2·1	−2·4	−2·7	−2·7	− 2·8	− 2·9	− 3·1	
Year	− 7·0	− 5·6	−2·7	+0·8	+4·0	+5·7	+ 7·1	+ 7·6	+ 7·8	+ 7·4	+ 6·6	+4·8	+2·5	+0·6	−0·6	−1·5	−2·4	−3·2	−3·9	−4·5	−5·2	− 5·8	− 6·3	− 6·8	

The numbers entered in the table for Bombay are the inequalities derived from the whole of the hourly observations of 1866 to 1872.

186. The diurnal variations expressed by these numbers are graphically represented by figures 373 to 437, the dotted figures referring to the group of monsoon months June to August. The curves show the same law of variation at all the stations in all seasons, but with diverse amplitudes. At all the stations the average diurnal range of temperature for the year is about double the range for the monsoon months June to August, and the range during the winter half year is generally large as compared with that of the summer half year; also the range is large at the inland station Deesa as compared with the coast station Kurrachee, and large inland at the elevated stations Belgaum and Poona as compared with the coast at Bombay. Comparing the three southern with the two northern stations, coast with coast, and inland with inland, we find an increase of range with increase of latitude; but between November and February, when the sun is farthest south, there is at all the low-lying stations, Bombay, Deesa, and Kurrachee, a slight diminution of range. The mean diurnal ranges for the stations Belgaum, Poona, Bombay, Deesa, and Kurrachee, taken in order are, for the year, 13°·3, 12°·1, 8°·8, 22°·0, and 14°·8; and for the months June to August 6°·4, 5°·7, 4°·6, 10°·4, and 7°·4.

187. In Table 105 and figures 503 to 507 we have also exhibited the mean temperature ranges in the different months, taken with respect to individual days, that is, the mean of the differences between the maximum and minimum temperatures of individual days. We have shown in the table, also the mean maximum and mean minimum temperatures derived from 18 years of almost complete series of daily observations of self-registering thermometers.

TABLE 105.

Station	BELGAUM.				POONA.				BOMBAY.				DEESA.				KURRACHEE.			
—	Mean Maximum.	Mean Minimum.	Range.	Annual Variation of Range.	Mean Maximum.	Mean Minimum.	Range.	Annual Variation of Range.	Mean Maximum.	Mean Minimum.	Range.	Annual Variation of Range.	Mean Maximum.	Mean Minimum.	Range.	Annual Variation of Range.	Mean Maximum.	Mean Minimum.	Range.	Annual Variation of Range.
January	86·1	57·8	28·3	+ 5·1	81·8	61·2	20·6	+4·4	82·0	67·4	14·6	+3·6	80·6	49·8	30·8	+ 5·2	76·1	51·8	24·3	+5·2
February	89·8	59·7	30·1	+ 6·9	85·7	64·5	21·2	+5·0	83·3	69·2	14·1	+3·1	85·5	54·3	31·2	+ 5·6	80·2	55·7	24·5	+5·4
March	96·0	63·2	32·8	+ 9·6	90·9	69·7	21·2	+5·0	85·4	73·1	12·3	+1·3	93·7	62·6	31·1	+ 5·5	85·7	63·4	22·3	+3·2
April	98·4	66·4	32·0	+ 8·8	95·6	74·9	20·7	+4·5	88·8	77·4	11·4	+0·4	102·2	71·5	30·7	+ 5·1	91·0	71·8	19·2	+0·1
May	94·5	67·0	27·5	+ 4·3	94·3	75·6	18·7	+2·5	91·0	80·7	10·3	−0·7	105·4	78·4	27·0	+ 1·4	93·4	77·4	16·0	−3·1
June	83·3	67·0	16·3	− 6·9	85·7	73·7	12·0	−4·2	88·4	79·7	8·7	−2·3	102·1	81·3	20·8	− 4·8	94·5	81·1	13·4	−5·7
July	78·0	66·5	11·5	−11·7	80·3	71·8	8·5	−7·7	85·1	78·1	7·0	−4·0	93·0	78·7	14·3	−11·3	91·2	80·0	11·2	−7·9
August	78·3	65·9	12·4	−10·8	79·1	70·6	8·5	−7·7	84·1	77·2	6·9	−4·1	87·9	76·1	11·8	−13·8	88·2	77·8	10·4	−8·7
September	81·4	64·9	16·5	− 6·7	80·7	70·1	10·6	−5·6	84·9	76·6	8·3	−2·7	90·8	74·4	16·4	− 9·2	88·7	75·7	13·0	−6·1
October	86·2	64·5	21·7	± 1·5	84·6	69·5	15·1	−1·1	87·2	76·1	11·1	+0·1	94·5	66·4	28·1	+ 2·5	90·7	69·1	21·6	+2·5
November	85·0	61·1	23·9	+ 0·7	82·9	64·5	18·4	+2·2	86·8	73·2	13·6	+2·6	89·8	56·7	33·1	+ 7·5	87·7	60·3	27·4	+8·3
December	84·1	58·7	25·4	+ 2·2	81·1	61·8	19·3	+3·1	84·1	70·0	14·1	+3·1	83·8	51·6	32·2	+ 6·6	80·0	53·8	26·2	+7·1
Year	86·8	63·6	23·2		85·2	69·0	16·2		85·9	74·9	11·0		92·4	66·8	25·6		87·3	68·2	19·1	

Although the diversity of manner of exposure of the thermometers at the different stations, and at the same station in different periods, renders these results less rigidly comparable than could be desired, they are yet of some interest, if the facts regarding the exposure be carefully kept in mind.

188. *Maxima and Minima.*—Table 106 shows for each month of the year the greatest and least values of the temperature of the air observed at the several stations.

TABLE 106.

	January.			February.			March.			April.			May.			June.		
	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
Belgaum	95·4	50·0	45·4	99·7	47·3	52·4	103·9	50·2	53·7	109·5	54·4	55·1	108·2	59·0	49·2	103·1	61·2	41·9
Poona	88·7	49·4	39·3	96·3	53·0	43·3	100·6	55·0	45·6	103·5	60·0	43·5	104·6	66·0	38·6	99·5	66·4	33·1
Bombay	91·5	55·5	96·0	96·5	57·5	39·0	100·5	64·4	36·1	97·9	72·7	25·2	96·5	76·0	20·5	96·0	74·0	22·0
Deesa	90·5	38·0	52·5	99·6	36·0	63·6	106·5	39·4	67·1	113·4	50·6	62·8	116·0	60·4	55·6	117·8	69·8	48·0
Kurrachee	96·3	38·1	58·2	101·4	38·2	63·2	102·4	45·5	56·9	109·6	57·9	51·7	110·5	66·0	44·5	117·8	69·5	48·3

TABLE 106—*continued.*

	July.			August.			September.			October.			November.			December.		
	Maximum.	Minimum.	Range	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
Belgaum	92·5	62·7	29·8	93·5	61·5	32·0	93·0	59·4	33·6	95·7	53·0	42·7	94·0	49·0	45·0	92·6	46·7	45·9
Poona	92·4	65·8	26·6	87·6	64·2	23·4	86·7	62·1	24·6	92·3	57·4	34·9	92·0	48·2	43·8	87·6	47·3	40·3
Bombay	93·0	73·4	19·6	90·0	73·8	16·2	94·4	73·0	21·4	93·5	71·0	22·5	93·4	66·0	27·4	96·0	61·2	34·8
Deesa	109·5	70·1	39·4	100·4	69·8	30·6	119·2	64·0	55·2	103·6	52·2	51·4	99·3	41·8	57·5	95·0	38·0	57·0
Kurrachee	104·5	70·5	34·0	105·4	72·0	33·4	109·5	69·4	40·1	108·8	55·5	53·3	110·2	47·5	62·7	101·8	40·8	61·0

189. The curves of figures 503 to 507, which have been constructed from the numbers in this table, show the extreme limits on the thermometer scale, beyond which the oscillations of temperature in the respective months have not extended. The vertical lines of the several months by their lengths show the absolute ranges of temperature, and by their extremities mark the limits. The interruption by the monsoon of the seasonal progress of the annual curves of upper limits is strongly marked at every station, but the curves of lower limits are but little affected. The absolute ranges, like the diurnal ranges, are great in the winter months, and relatively small in the summer months, and especially during the monsoon. During the monsoon the least absolute range is found at Bombay, the next greater at Poona, and the next at Belgaum; the absolute ranges for the same period of Deesa and Kurrachee, which are of about equal extent, are both still greater.

PRESSURE OF VAPOUR.

190. The values of the pressure of vapour made use of have been calculated by Glaisher's Hygrometrical Tables from the observed temperatures of the dry and wet bulb thermometers.

Tables and curves have been constructed to represent the secular, annual, and diurnal variations, and the absolute extremes, in the same manner that has been described in dealing with barometric pressures and temperatures. The tables are numbered 107 to 114, and the figures 268 to 272, 288 to 292, 438 to 502, and 513 to 517. In regard to secular variation the results for Deesa and Kurrachee are evidently too much affected by instrumental or other irregularities to be of any use, but the three other stations show some similarity of movement from year to year; and the average excesses for these stations for the periods 1856 to 1860, 1861 to 1866, and 1867 to 1874 lend some support to the inference already drawn (paragraph 76) from the long period of Bombay observations, that the vapour pressure is subject to a decennial variation; the average excesses are +·007, −·017, and +·011 inch respectively, agreeing in order of succession and sign with those

of Bombay alone. The annual variations are similar in character at all the stations, giving high values of the vapour pressure in the summer and monsoon months, May to September, and low values in the winter months; but the high values at Deesa appear later and disappear earlier than at the other stations, and the curve is nearly in the form of a curve of sines, whilst the curves of the four other stations all exhibit a strongly-marked flattening of the upward convexity during the monsoon months. At these stations the month of maximum vapour pressure is June; at Deesa it is July. The mean diurnal variation for the year shows at all the stations a minimum towards the end of the night hours, and a maximum near the beginning of the night hours, with a fairly regular progression during the intervals, except at Deesa, where a principal maximum is found about 10 a.m., and the values continue high till 7 p.m. At Belgaum and Poona, as at Bombay, the monsoon variation has high values during the day hours and low values during the night. The diurnal range of the monsoon months is very small at Poona and Kurrachee as compared with the range of the winter months; at the other stations also it is smaller, but the low range continues at Belgaum till late in the year, a result which agrees with the late continuance of the rains of the southern part of the Deccan.

TABLE 107.

SHOWING the MEAN PRESSURE of VAPOUR, derived from OBSERVATIONS at 9.30 a.m. and 3.30 p.m., for each YEAR of COMPLETE OBSERVATIONS at each Station.

Year.	BELGAUM.		POONA.		BOMBAY.		DEESA.		KURRACHEE.	
	Mean Pressure of Vapour.	Excess above General Mean.	Mean Pressure of Vapour.	Excess above General Mean.	Mean Pressure of Vapour.	Excess above General Mean.	Mean Pressure of Vapour.	Excess above General Mean.	Mean Pressure of Vapour.	Excess above General Mean.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
1856	·634	+ ·044	·574	− ·007	·790	+ ·011			·714	+ ·031
1857	·580	− ·010	·552	− ·029	·786	+ ·007	·642	+ ·002	·686	+ ·003
1858	·615	+ ·025			·809	+ ·030	·617	− ·023	·693	+ ·010
1859	·571	− ·019	·612	+ ·031	·809	+ ·030	·620	− ·020	·643	− ·040
1860	·560	− ·030	·570	− ·011	·794	+ ·015			·658	− ·025
1861	·551	− ·039	·550	− ·031	·768	− ·011	·626	− ·014	·625	− ·058
1862	·585	− ·005	·562	− ·019	·766	− ·013	·696	+ ·056	·647	− ·036
1863			·550	− ·031	·750	− ·029	·730	+ ·090	·618	− ·065
1864	·547	− ·043	·549	− ·032	·737	− ·042	·768	+ ·128	·641	− ·042
1865	·595	+ ·005	·602	+ ·021	·784	+ ·005	·838	+ ·198	·644	− ·039
1866	·571	− ·019	·591	+ ·010	·777	− ·002	·625	− ·015	·624	− ·059
1867	·643	+ ·053	·600	+ ·019	·788	+ ·009				
1868	·602	+ ·012	·584	+ ·003	·784	+ ·005				
1869	·586	− ·004	·617	+ ·036	·784	+ ·005	·581	− ·059	·790	+ ·107
1870	·594	+ ·004	·591	+ ·010	·765	− ·014	·567	− ·073	·738	+ ·055
1871	·599	+ ·009	·615	+ ·034	·791	+ ·012	·563	− ·077	·704	+ ·021
1872	·619	+ ·029	·591	+ ·010	·760	− ·019	·548	− ·092	·682	− ·001
General Means -	·590		·581		·779		·640		·683	
Additional Years - 1873	·608	+ ·018	·588	+ ·007	·785	+ ·006	·530	− ·110	·666	− ·017
Additional Years - 1874	·599	+ ·009	·591	+ ·010	·775	− ·004	·533	− ·107	·650	− ·033

The curves constructed from the numbers in this table are numbered 268 to 272,

Table 108.

Showing the Excess of the Mean Vapour Pressure in each Month above the Mean of the Year; first, as deduced from Observations taken daily at the Hours 9.30 a.m. and 3.30 p.m.; and secondly, after correction for the Diurnal Inequality at those Hours.

		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
From Observations at 9.30 a.m. and 3.30 p.m.	Belgaum - -	−·123	−·122	−·086	−·019	+·070	+·120	+·110	+·100	+·086	+·033	−·062	−·105
	Poona - -	−·127	−·134	−·096	−·045	+·035	+·141	+·136	+·125	+·107	+·042	−·076	−·107
	Bombay - -	−·169	−·153	−·073	+·027	+·077	+·133	+·130	+·106	+·088	+·060	−·090	−·136
	Deesa - -	−·214	−·186	−·147	−·055	+·044	+·175	+·232	+·232	+·186	+·028	−·114	−·183
	Kurrachee - -	−·268	−·217	−·097	+·042	+·173	+·235	+·222	+·178	+·134	+·010	−·165	−·250
Corrected for Diurnal Inequality.	Belgaum - -	−·116	−·112	−·064	+·007	+·087	+·108	+·093	+·076	+·068	+·036	−·069	−·116
	Poona - -	−·134	−·136	−·083	−·018	+·064	+·129	+·117	+·107	+·096	+·047	−·078	−·115
	Bombay - -	−·192	−·184	−·072	+·032	+·095	+·152	+·125	+·103	+·090	+·068	−·087	−·135
	Deesa - -	−·231	−·204	−·155	−·053	+·089	+·199	+·249	+·244	+·195	+·021	−·146	−·211
	Kurrachee - -	−·273	−·220	−·091	+·040	+·176	+·246	+·227	+·181	+·140	+·017	−·180	−·262

The curves constructed from the numbers in this table are numbered 288 to 292.

Tables showing the Excess of the Mean Pressure of Vapour at each Hour of the Day in each Month above the Mean of the 24 Hours, and the Number of Complete Days' Observations from which the Numbers are derived.

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Table 109.

BELGAUM.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	
January - -	−·058	−·049	−·034	−·019	−·009	−·002	−·002	+·006	+·005	+·001	+·008	+·020	+·035	+·049	+·045	+·044	+·030	+·022	+·009	−·005	−·009	−·019	−·032	−·043	16
Feb uary -	−·045	−·037	−·023	−·023	−·015	−·017	−·020	−·015	−·011	−·002	+·007	+·024	+·041	+·066	+·060	+·065	+·041	+·030	+·018	−·003	−·018	−·027	−·039	−·050	17
March - -	−·044	−·023	−·020	−·034	−·052	−·048	−·046	−·045	−·033	−·005	+·011	+·037	+·068	+·074	+·062	+·055	+·055	+·037	+·020	+·015	+·003	−·010	−·029	−·037	17
April - -	+·027	−·026	−·015	−·040	−·057	−·055	−·049	−·052	−·040	−·017	+·017	+·027	+·051	+·058	+·055	+·048	+·045	+·042	+·018	+·011	+·001	+·002	·000	−·004	17
May - -	−·011	+·005	−·001	−·015	−·026	−·047	−·047	−·054	−·044	−·019	+·001	+·025	+·033	+·050	+·041	+·037	+·027	+·020	+·008	+·008	+·008	+·005	−·003	−·001	16
June - -	−·014	+·003	+·004	+·016	+·018	+·020	+·025	+·025	+·028	+·013	+·011	+·008	+·006	−·002	−·001	−·008	−·012	−·014	−·017	−·018	−·022	−·026	−·024	−·017	16
July - -	−·026	−·013	+·002	+·010	+·018	+·032	+·031	+·035	+·031	+·028	+·021	+·012	+·003	+·001	−·004	−·012	−·016	−·025	−·019	−·022	−·022	−·021	−·022	−·025	16
August - -	−·030	−·017	+·001	+·012	+·023	+·033	+·035	+·039	+·036	+·039	+·030	+·016	+·012	+·003	−·009	−·010	−·014	−·019	−·023	−·027	−·028	−·032	−·032	−·038	15
September -	−·029	−·016	·000	+·005	+·012	+·016	+·025	+·028	+·033	+·036	+·028	+·024	+·018	+·014	+·008	−·003	−·012	−·013	−·021	−·025	−·028	−·032	−·035	−·032	15
October - -	·000	·000	+·006	+·009	+·003	−·006	−·009	−·013	+·001	−·002	−·012	+·009	+·020	+·025	+·018	+·014	+·013	+·003	·000	−·002	−·009	−·016	−·026	−·023	15
November -	−·017	−·010	+·003	+·021	+·017	+·017	+·013	+·009	+·008	+·004	+·004	+·016	+·038	+·035	+·021	+·012	+·003	−·008	−·015	−·024	−·028	−·039	−·044	−·045	12
December -	−·021	−·016	−·006	+·014	+·010	+·011	+·006	+·008	+·008	+·016	+·011	+·010	+·033	+·031	+·019	+·013	+·003	+·004	−·008	−·021	−·026	−·030	−·035	−·039	13
June to August	−·023	−·009	+·002	+·013	+·020	+·028	+·030	+·033	+·032	+·027	+·021	+·012	+·007	+·001	−·005	−·010	−·014	−·019	−·020	−·022	−·024	−·026	−·026	−·027	
Year - -	−·027	−·017	−·007	−·004	−·005	−·004	−·004	−·003	+·001	+·007	+·011	+·019	+·029	+·033	+·026	+·021	+·013	+·006	−·003	−·010	−·015	−·021	−·027	−·030	

TABLE 110.

POONA.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	
January - -	−·043	−·047	−·034	−·026	−·014	−·005	+·011	+·018	+·018	+·021	+·027	+·026	+·029	+·035	+·037	+·045	+·030	+·023	+·011	−·002	−·025	−·037	−·042	−·059	20
February -	−·034	−·035	−·027	−·013	−·018	−·006	+·005	+·011	+·014	+·016	+·004	+·009	+·015	+·025	+·029	+·039	+·025	+·019	+·020	+·002	−·007	−·015	−·032	−·036	20
March - -	+·010	+·009	+·007	−·005	−·012	−·025	−·025	−·027	−·040	−·014	−·040	−·027	−·015	+·008	+·026	+·036	+·043	+·040	+·036	+·030	+·013	+·004	−·008	−·016	21
April - -	−·021	−·023	−·015	−·021	−·030	−·027	−·038	−·050	−·052	−·045	−·031	−·008	+·017	+·028	+·058	+·059	+·050	+·048	+·040	+·037	+·020	+·012	+·002	−·008	21
May - -	+·018	+·025	+·012	−·003	−·034	−·039	−·046	−·052	−·060	−·058	−·039	−·012	−·006	+·022	+·030	+·039	+·056	+·042	+·038	+·022	+·023	+·007	·000	+·007	21
June - -	+·002	+·009	+·009	+·005	+·009	+·005	+·011	+·002	+·004	+·010	+·004	·000	−·001	−·004	−·002	+·002	+·001	−·001	−·003	−·005	−·010	−·009	−·010	−·016	20
July - -	−·009	−·004	+·001	+·011	+·015	+·016	+·018	+·015	+·027	+·018	+·013	−·006	+·001	+·003	−·003	−·005	−·004	−·012	−·013	−·012	−·015	−·012	−·017	−·020	21
August - -	−·013	−·008	−·002	+·012	+·015	+·014	+·015	+·015	+·020	+·015	+·011	+·001	−·004	+·001	−·001	+·003	−·001	−·004	−·006	−·006	−·015	−·019	−·019	−·021	21
September -	−·017	−·008	+·004	+·010	+·009	+·015	+·018	+·007	+·004	+·003	+·001	+·009	+·002	+·008	+·006	+·003	+·005	+·002	−·002	−·008	−·011	−·016	−·023	−·023	20
October - -	−·018	−·008	−·011	−·014	−·009	−·011	−·018	−·029	−·012	−·011	−·005	−·005	+·006	+·008	+·023	+·035	+·035	+·027	+·026	+·016	+·001	−·009	−·008	−·003	20
November -	−·016	−·020	−·012	−·019	+·001	+·014	+·010	+·011	+·004	+·006	+·002	+·011	+·015	+·027	+·033	+·033	+·027	+·013	+·005	−·007	−·026	−·035	−·043	−·040	18
December -	−·038	−·031	−·025	−·026	−·009	+·011	+·022	+·025	+·026	+·028	+·019	+·026	+·031	+·034	+·031	+·030	+·023	+·019	−·002	−·016	−·027	−·039	−·050	−·053	20
June to August	−·007	−·001	+·003	+·009	+·013	+·012	+·015	+·011	+·017	+·014	+·009	−·002	−·001	·000	−·002	·000	−·001	−·006	−·007	−·008	−·013	−·013	−·015	−·019	
Year - -	−·015	−·012	−·008	−·008	−·007	−·003	−·002	−·005	−·004	−·001	−·003	+·002	+·007	+·016	+·022	+·026	+·024	+·018	+·012	+·004	−·007	−·014	−·021	−·024	

TABLE 111.

BOMBAY.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	
January -	−·049	−·052	−·040	−·037	−·035	−·036	−·018	+·001	+·031	+·047	+·056	+·052	+·051	+·050	+·045	+·033	+·016	−·001	·000	−·003	−·012	−·020	−·033	−·043	180
February -	−·045	−·045	−·041	−·041	−·036	−·034	−·013	+·018	+·039	+·051	+·049	+·042	+·037	+·032	+·025	+·021	+·008	−·001	−·003	−·004	−·004	−·012	−·016	−·029	164
March - -	−·027	−·026	−·021	−·027	−·021	+·001	+·008	+·020	+·024	+·020	+·013	+·004	+·001	·000	+·002	+·007	+·007	+·007	+·008	+·009	+·009	+·003	−·005	−·014	175
April - -	−·026	−·015	−·013	−·013	−·014	+·006	+·012	+·017	+·019	+·013	+·011	+·008	+·002	+·001	+·005	+·009	+·009	+·009	+·003	−·001	−·007	−·010	−·020	−·025	176
May - -	−·020	−·012	−·009	−·005	−·005	−·002	+·006	+·011	+·016	+·019	+·017	+·017	+·013	+·010	+·010	+·009	+·008	+·003	−·005	−·009	−·014	−·017	−·021	−·023	179
June - -	−·018	−·012	−·004	+·008	+·012	+·014	+·020	+·023	+·025	+·024	+·017	+·008	+·002	−·006	−·006	−·006	−·006	−·008	−·009	−·012	−·010	−·015	−·019	−·021	180
July - -	−·018	−·009	+·002	+·011	+·017	+·025	+·027	+·032	+·026	+·021	+·012	·000	−·007	−·009	−·009	−·012	−·010	−·010	−·009	−·014	−·016	−·018	−·019	−·021	186
August - -	−·018	−·009	+·002	+·012	+·024	+·027	+·029	+·032	+·027	+·017	+·011	−·001	−·006	−·012	−·012	−·011	−·012	−·011	−·011	−·014	−·014	−·017	−·020	−·021	181
September -	−·017	−·004	+·008	+·022	+·027	+·034	+·034	+·032	+·029	+·021	+·009	−·005	−·013	−·014	−·014	−·014	−·015	−·013	−·013	−·016	−·016	−·019	−·018	−·018	179
October - -	−·032	−·013	−·005	−·001	−·002	−·003	−·001	+·011	+·025	+·030	+·032	+·023	+·019	+·019	+·017	+·009	−·003	−·013	−·011	−·016	−·017	−·021	−·028	−·030	182
November -	−·039	−·030	−·031	−·035	−·042	−·053	−·062	−·034	+·001	+·031	+·052	+·055	+·062	+·062	+·061	+·041	+·019	+·009	+·013	+·004	−·008	−·016	−·025	−·034	178
December -	−·039	−·031	−·027	−·034	−·039	−·042	−·044	−·026	+·006	+·023	+·039	+·046	+·053	+·057	+·055	+·039	+·016	+·003	+·004	·000	−·006	−·013	−·019	−·031	179
June to August	−·018	·010	·000	+·010	+·018	+·022	+·025	+·029	+·026	+·021	+·013	+·002	−·004	−·009	−·009	−·010	−·009	−·010	−·010	−·013	−·013	−·017	−·019	−·021	
Year - -	−·028	−·021	−·014	−·011	−·008	−·005	−·002	+·012	+·023	+·027	+·027	+·021	+·018	+·016	+·015	+·011	+·004	−·002	−·002	−·006	−·009	−·014	−·020	−·025	

TABLE 112.

DEESA.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	
January	−·063	−·063	−·034	+·008	+·037	+·051	+·052	+·053	+·058	+·066	+·063	+·056	+·052	+·034	+·013	−·013	−·021	−·032	−·031	−·041	−·051	−·058	−·063	−·069	12
February	−·094	−·100	−·051	+·018	+·044	+·058	+·068	+·067	+·067	+·053	+·062	+·038	+·081	+·064	+·037	+·021	−·008	−·020	−·038	−·055	−·067	−·064	−·086	−·088	12
March	−·080	−·068	−·026	+·016	+·032	+·054	+·050	+·042	+·052	+·040	+·050	+·041	+·055	+·059	+·039	+·021	−·009	−·016	−·042	−·049	−·048	−·067	−·062	−·086	12
April	−·063	+·007	+·042	+·041	+·047	+·034	+·016	+·013	+·012	+·004	+·003	+·008	+·004	+·043	+·029	+·002	−·004	−·002	−·021	−·022	−·045	−·046	−·052	−·060	12
May	+·034	+·043	+·042	+·023	+·018	+·007	−·022	−·021	−·059	−·071	−·045	−·061	−·043	−·012	−·027	−·002	+·013	−·002	+·022	+·034	+·033	+·031	+·031	+·033	13
June	+·031	+·035	+·032	+·026	+·017	+·006	+·003	−·014	−·015	−·025	−·011	−·021	−·023	−·020	−·025	−·021	−·015	−·002	·000	+·014	+·019	+·003	+·001	+·006	12
July	−·039	−·020	−·005	·000	+·018	+·027	+·015	+·006	+·017	+·014	+·004	−·001	+·003	+·022	+·018	+·002	+·006	+·003	−·002	+·005	−·011	−·019	−·027	−·025	14
August	−·034	−·021	−·002	+·012	+·021	+·018	+·023	+·020	+·018	+·013	+·009	+·011	+·021	+·023	+·013	+·003	·000	·000	−·010	−·016	−·020	−·024	−·028	−·056	14
September	−·023	−·002	+·018	+·028	+·016	+·008	+·016	+·014	+·010	+·015	+·010	+·017	+·022	+·019	+·012	+·006	−·005	−·006	−·010	−·024	−·032	−·035	−·032	−·044	13
October	−·056	−·021	+·022	+·035	+·039	+·033	+·042	+·024	+·019	+·028	+·029	+·064	+·054	+·031	+·007	+·007	−·007	−·027	−·034	−·045	−·059	−·048	−·064	−·064	11
November	−·081	−·077	−·024	+·033	+·066	+·070	+·085	+·064	+·069	+·067	+·068	+·089	+·054	+·025	+·008	−·022	−·029	−·037	−·055	−·065	−·073	−·078	−·081	−·084	12
December	−·079	−·069	−·039	+·017	+·055	+·076	+·071	+·078	+·078	+·074	+·069	+·064	+·057	+·021	−·001	−·020	−·034	−·036	−·048	−·061	−·057	−·066	−·069	−·076	12
June to August	−·014	−·002	+·008	+·013	+·019	+·017	+·014	+·004	+·007	+·001	+·001	−·004	·000	+·008	+·002	−·005	−·003	·000	−·004	−·002	−·004	−·013	−·018	−·025	
Year	−·045	−·029	−·002	+·022	+·034	+·037	+·035	+·029	+·027	+·023	+·026	+·026	+·028	+·026	+·010	−·001	−·009	−·015	−·022	−·028	−·034	−·039	−·044	−·051	

TABLE 113.

KURRACHEE.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	Number of Days' Observations.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	
January	−·058	−·060	−·056	−·022	−·002	+·022	+·022	+·031	+·037	+·027	+·034	+·025	+·042	+·032	+·023	+·019	+·009	+·006	−·005	−·006	−·011	−·030	−·037	−·050	16
February	−·075	−·068	−·046	−·017	−·005	+·001	+·002	+·008	+·005	+·023	+·027	+·040	+·059	+·051	+·050	+·034	+·006	·000	+·005	+·002	−·004	−·018	−·031	−·043	16
March	−·043	−·036	−·015	−·007	−·035	−·025	−·015	−·012	+·004	+·016	+·017	+·028	+·021	+·035	+·040	+·036	+·030	+·025	+·011	+·008	+·001	−·016	−·022	−·038	16
April	−·015	+·001	+·009	+·008	−·010	−·015	−·028	−·024	−·014	+·013	+·012	+·012	+·026	+·030	+·019	+·007	+·010	+·007	+·007	+·002	−·004	−·009	−·022	−·026	17
May	−·006	−·007	−·001	+·001	−·007	−·005	−·009	+·012	+·007	+·008	+·003	+·011	+·017	+·025	+·019	+·017	+·011	+·007	−·003	−·007	−·013	−·022	−·029	−·035	17
June	·000	·000	−·004	−·007	−·012	−·007	−·015	−·006	−·004	−·006	−·003	+·004	+·004	+·011	+·016	+·016	+·017	−·003	+·005	+·001	−·002	−·001	−·005	−·007	17
July	+·004	+·005	+·011	+·011	+·012	·000	+·005	−·001	−·009	−·015	−·013	−·009	−·006	−·001	+·002	+·005	+·004	+·005	−·007	−·012	−·011	−·005	+·004	+·012	17
August	−·021	·000	+·005	+·004	·000	+·006	−·007	−·005	−·004	−·001	+·002	+·006	+·007	+·019	+·009	+·008	+·007	+·007	+·005	−·001	−·005	−·007	−·010	−·013	18
September	+·005	+·017	+·006	+·010	−·001	−·013	−·018	−·015	−·007	−·009	−·007	+·001	+·005	−·002	−·002	+·001	+·004	+·002	+·004	+·004	+·001	+·003	+·003	+·003	16
October	−·028	−·008	+·032	+·019	−·022	−·010	−·013	−·018	−·027	−·012	+·004	+·029	+·054	+·065	+·050	+·054	+·050	+·022	+·004	+·006	−·034	−·055	−·078	−·088	15
November	−·092	−·078	−·036	+·001	+·008	+·010	+·008	+·024	+·038	+·032	+·039	+·076	+·097	+·076	+·046	+·031	+·015	−·005	−·009	−·029	−·049	−·057	−·064	−·069	16
December	−·088	−·085	−·060	−·023	+·017	+·037	+·048	+·058	+·036	+·030	+·038	+·054	+·065	+·047	+·032	+·024	+·020	+·002	−·018	−·028	−·032	−·051	−·057	−·064	16
June to August	−·006	+·002	+·004	+·003	·000	·000	−·006	−·004	−·006	−·007	−·005	·000	+·002	+·010	+·009	+·010	+·009	+·003	+·001	−·004	−·006	−·004	−·004	−·003	
Year	−·034	−·026	−·013	−·001	−·005	·000	−·001	+·005	+·006	+·009	+·013	+·023	+·033	+·033	+·026	+·021	+·016	+·007	·000	−·005	−·013	−·022	−·029	−·034	

The curves constructed from the numbers in Tables 109 to 113 are numbered 438 to 502 respectively.

TABLE 114.

SHOWING, for each Month of the Year, the Greatest and Least VALUES of the PRESSURE of VAPOUR observed at 9.30 a.m. or 3.30 p.m. at the several Stations.

	January.			February.			March.			April.			May.			June.		
	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Belgaum	·653	·279	·374	·776	·302	·474	·838	·309	·529	·914	·303	·611	1·101	·381	·720	·955	·497	·458
Poona	·686	·244	·442	·688	·276	·412	·787	·261	·526	·814	·302	·512	·860	·373	·487	·891	·499	·392
Bombay	·854	·319	·535	·882	·321	·561	·947	·303	·644	1·040	·553	·487	1·075	·685	·390	1·048	·655	·393
Deesa	·889	·209	·680	·882	·194	·688	1·109	·242	·867	1·262	·288	·974	1·195	·349	·846	1·199	·425	·774
Kurrachee	·884	·210	·674	·868	·207	·661	·959	·215	·744	1·043	·295	·748	1·159	·306	·853	1·197	·383	·814

TABLE 114—*continued.*

	July.			August.			September.			October.			November.			December.		
	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Belgaum	·826	·619	·207	·818	·609	·209	·812	·506	·306	·827	·399	·428	·727	·314	·413	·649	·304	·345
Poona	·889	·607	·282	·938	·628	·310	·918	·500	·418	·843	·363	·480	·750	·304	·446	·732	·266	·466
Bombay	1·120	·787	·333	·994	·780	·214	1·007	·710	·297	1·017	·523	·494	·976	·430	·546	·933	·380	·553
Deesa	1·206	·603	·603	1·230	·656	·574	1·117	·455	·662	1·111	·314	·797	1·074	·288	·786	·926	·232	·694
Kurrachee	1·116	·743	·373	1·148	·654	·494	1·068	·497	·571	1·086	·265	·821	·922	·252	·670	·808	·200	·608

The curves constructed from the numbers in this table are numbered 513 to 517.

CLOUDINESS.

191. The cloudiness of the sky is estimated in tenths of the celestial hemisphere, the unit being one-tenth of the whole sky. In Part I. the unit used for the *hourly observations* at Bombay is correctly stated to be one-eighth of the whole sky.

TABLE 115.

SHOWING the AVERAGE CLOUDINESS of the SKY at each Station in each Month of the Year, derived from OBSERVATIONS at 9.30 a.m. and 3.30 p.m.

	BELGAUM.	POONA.	BOMBAY.	DEESA.	KURRACHEE.
January	2·7	2·3	2·3	2·1	4·0
February	2·3	1·3	1·4	1·6	2·8
March	3·1	2·4	2·0	2·5	4·2
April	4·1	2·9	2·3	1·8	2·8
May	5·2	4·0	4·3	1·3	3·7
June	8·2	7·9	8·0	4·9	6·1
July	8·6	8·8	9·3	7·8	8·8
August	8·4	8·6	9·3	8·1	8·6
September	7·6	7·2	7·8	5·6	5·3
October	6·0	4·6	4·5	1·9	2·2
November	4·0	2·8	2·7	1·2	2·1
December	3·0	2·1	2·1	1·7	3·0
May to October	7·3	6·8	7·2	4·9	5·8
November to April	3·2	2·3	2·1	1·8	3·1
Year	5·3	4·6	4·7	3·4	4·5

These numbers are curved in figures 303 to 307.

From the numbers in the last three lines we observe that the cloudiness is great everywhere during the monsoon months, and small during the winter, but, like the rain, the cloudiness of the monsoon is much greater at the Konkan and Deccan stations than at the Guzerat and Sind stations. At all the stations, except Belgaum, there is a slight excess in January above the cloudiness of the preceding and following months; and in March again the cloudiness is slightly greater at Deesa and Kurrachee than in February and April. At Belgaum we note, too, that the cloudiness is in October more considerable than elsewhere, which again is in agreement with the late continuance of the rains there.

Rainfall.

192. The total rainfall, in inches, of each year for which a complete record exists is shown in the following table for each of the five stations; and the numbers, which extend over the 19 years from 1856 to 1874, are curved in figures 273 to 277.

Table 116.

Year.	Belgaum.	Poona.	Bombay.	Deesa.	Kurrachee.
	Inches.	Inches.	Inches.	Inches.	Inches.
1856	53·92	21·29	65·92	26·48	1·91
1857	66·47	28·96	51·27	29·17	5·68
1858	43·72		62·45	25·80	7·87
1859	56·38	41·93	77·16	20·59	6·20
1860	42·98	39·20	62·15		2·81
1861	64·69	57·79	76·91	19·81	6·85
1862	57·35	33·43	73·63	38·94	4·87
1863		26·00	77·68	35·40	13·90
1864	44·05	22·34	45·57	28·23	6·28
1865	51·18	34·27	77·85	22·84	7·06
1866	52·14	23·34	78·44	15·93	13·72
1867	43·32	30·98	62·30	20·22	2·41
1868	56·44	38·14	62·12	18·41	3·58
1869	54·78	27·63	91·66	33·38	28·45
1870	62·14	37·79	66·21	27·35	4·65
1871	40·74	28·92	40·58	24·71	·48
1872	50·99	22·87	76·48	24·42	7·60
1873	45·41	26·58	69·70	17·12	2·50
1874	63·62	39·06	82·18	27·01	8·54

In Table 117 is shown the average rainfall of each month, and of the full year, for each of the five stations.

TABLE 117.

Month.	BELGAUM.	POONA.	BOMBAY.	DEESA.	KURRACHEE.
	Inches.	Inches.	Inches.	Inches.	Inches.
January -	·12	·43	·12	·19	·80
February -	·00	·06	·01	·14	·21
March -	·45	·31	·00	·14	·16
April -	2·05	·56	·04	·00	·00
May -	3·26	1·56	·53	·10	·09
June -	11·23	6·19	20·45	2·83	·24
July -	16·02	6·89	24·12	9·28	2·59
August -	11·01	5·09	12·83	9·24	2·05
September -	2·84	4·65	9·65	2·55	·90
October -	4·90	5·54	2·02	1·14	·12
November -	·75	·52	·49	·13	·03
December -	·56	·29	·05	·03	·21
Year -	53·19	32·09	70·30	25·77	7·40

The numbers in this table for Bombay are means for the years 1847 to 1874, and for the four other stations the means for the years 1856 to 1872.

Table 118 shows the average number of rainy days in each month, and in the full year, for each of the five stations.

TABLE 118.

Month.	BELGAUM.	POONA.	BOMBAY.	DEESA.	KURRACHEE.
January -	·2	·5	·2	·7	2·0
February -	·1	·2	·1	·4	·7
March -	1·5	1·0	·1	·4	·9
April -	4·7	1·5	·3	·1	·1
May -	6·3	3·5	1·9	·4	·2
June -	20·3	14·2	21·4	4·4	1·2
July -	25·2	20·1	27·3	12·4	3·0
August -	24·3	19·8	25·8	14·2	3·8
September -	14·2	10·4	19·0	5·2	1·3
October -	10·8	7·4	4·3	1·3	·2
November -	2·2	1·7	1·1	·7	·2
December -	1·1	·9	·3	·2	·8
Year -	110·9	81·2	101·9	40·4	14·4

Table 119 shows the greatest fall of rain recorded in any one day in each month, and the greatest fall in any one year, during the periods 1847 to 1874 for Bombay, and 1856 to 1872 for the other stations.

TABLE 119.

Month.	BELGAUM.	POONA.	BOMBAY.	DEESA.	KURRACHEE.
	Inches.	Inches.	Inches.	Inches.	Inches.
January -	1·06	4·68	1·87	1·62	2·22
February -	·05	·66	·11	·90	1·14
March -	·83	·90	·03	1·30	·53
April -	2·28	2·10	·47	·08	·05
May -	4·63	3·15	1·78	·78	·93
June -	5·51	5·00	15·31	3·75	1·39
July -	5·83	3·56	8·14	6·40	6·74
August -	6·07	2·80	10·23	8·98	4·83
September -	2·20	3·32	9·23	4·50	6·50
October -	2·87	7·90	2·99	1·95	1·45
November -	2·19	1·60	2·48	·68	·46
December -	2·60	1·08	·83	·18	·83
Year -	66·47	57·79	114·89	38·94	28·45

The numbers of Tables 117 to 119 are curved in figures 293 to 302 and 518 to 522. As the rainfall will be discussed in some detail in Parts III. and IV., we forbear at present to make any remarks beyond noticing the similarity as to form, though not always as to the range, of the annual curves of rainfall and number of rainy days, and the fact that the months December to March are all but rainless at all the stations.

WIND.

193. From observations of the direction only of the wind, apart from observations of velocity or force, it is impossible to draw any secure conclusions about the average bodily motions of the atmosphere, measured mechanically, as movements in certain directions and with certain velocities. The formula of Lambert, which was designed to be used for the deduction of such conclusions from such data, Herschel* speaks of as being founded on a most misleading supposition, viz., that the force of the winds from different directions may be regarded, on the average, as measured by the frequency of their occurrence. If, however, we confine our attention to the relative frequency or duration of winds from different directions, Lambert's formula assumes a new significance, as the first, and generally a principal term in a strictly accurate expression for that element of the wind's

* Herschel's Meteorology (1862), page 80.

behaviour. Nearly half a century ago, Bessel pointed out that his method for the determination of the law of a periodical phenomenon might be applied to determine the influence of the wind on the readings of the meteorological instruments, and it has since been so applied on a large scale, especially by Professor Dove. In the ordinary application of the method the variable angle in Bessel's expression is an equivalent of time, at the rate of 2π per period, but when the method is used for the purpose just mentioned it is the azimuth of the wind, measured round the compass (say) from north through east, *i.e.*, by a right-handed rotation. Observations of the direction of the wind only, can serve no useful purpose, unless we suppose the observed direction to last for a finite interval of time, which may, however, be as small as we please. Taking then the smallest interval that we choose as a constant interval, during which all the observed directions shall be supposed to endure, the number of observations of a particular direction in a given time will bear to the total number of observations of all directions (including calms) in that time the same ratio as the aggregate of the intervals of time, which refer to the particular direction, bears to the aggregate of the intervals having reference to all directions; in other words, the ratio is the same as that of the duration of winds observed in the particular direction to the total duration of all the winds observed. If then n_θ denote the number of observations of the particular direction θ from north, or rather between the directions $\left(\theta - \frac{\Phi}{2}\right)$ and $\left(\theta + \frac{\Phi}{2}\right)$, and N be the total number of observations; and if these latter are made after equal intervals of time, and under similar circumstances, that is to say, at the same season of the year, and same hour of the day, so as to be comparable one with another, the observed ratios $\frac{n_\theta}{N}$, or the relative duration of the different winds, may be expressed by the following formula:—

$$\frac{n_\theta}{N} = a + R_1 \cos(\theta - \alpha_1) + R_2 \cos(2\theta - \alpha_2) + R_3 \cos(3\theta - \alpha_3) + \&c. \qquad (1)$$

in which a and the coefficients R_1, R_2, R_3, &c., and the angles α_1, α_2, α_3, &c., must be determined by Bessel's process, from the series of observed values of n_θ. It is here assumed that the directions have been observed, as is the universal practice, for equal arcs of the compass. Practice varies, however, as to the number of equal parts into which the whole circuit of the horizon is divided; sometimes it is 32, 16, or 8, in other cases it is 36 or 360; and it is obvious that at the same place, and out of the same total number of observations, a greater n_θ will be found if the compass is divided into a small number of points than if it is divided into a large number, that is, if observations included within a large arc are classed under the particular direction instead of those only under a small arc. Thus if $r\left(=\frac{2\pi}{\varphi}\right)$ be the number of different directions into which the compass is divided, the relative duration is $\frac{n_\theta}{N}$ per $\frac{1}{r}$ of the whole circumference, and to render the formulæ derived from the observations of different systems comparable we must apply a factor to make them all refer to the same arc; the factor for this purpose must be proportional to r, though otherwise it may be arbitrarily chosen, but the most convenient factor is r, because it corresponds to that arc (2π) for which the average of all the relative durations is equal to *unity*. The formula, if carried to $\left(\frac{r+2}{2}\right)$ terms, r being even, or to $\left(\frac{r+3}{2}\right)$ terms, r being

odd, will express the observed values of $\frac{n_\theta}{N}$ *exactly;* and the greater r is, the more nearly will the true values of $\frac{n_\theta}{N}$ be yielded for any other values of θ than those for which n_θ is observed. The first term a is the average relative duration for all directions, and is equal to the sum of the observed values of $\frac{n}{N}$ divided by r that is equal to $\frac{1}{r}$; the second term $R_1 \cos(\theta - \alpha_1)$ may be roughly described as expressing the preponderance of winds from some one side of the compass over those from the opposite side, the winds from intermediate directions balancing each other; the third term, the preponderance of winds from two opposite sides of the compass over those from the two intermediate directions; the fourth term, the preponderance from three equidistant directions over the three intermediate directions, and so on. Thus the later terms, the coefficients of which ordinarily become smaller as the number of the term increases, imply *frequent* alternations of relative duration as we proceed round the compass; and the search for the causes of such frequent alternations is undoubtedly one that may properly be deferred till the relations to other phenomena of the less frequent alternations represented by the earlier and generally more considerable terms have been discovered. Hence we may confine our attention to (say) the first three terms of the expression, which terms will, however, generally give fair approximations to the true relative durations for all values of θ.

The application of the factor r to equation (1) is equivalent to altering the arc of the compass to which the relative durations refer from ϕ to 2π, for

$\frac{n_\theta}{N}$ is the relative duration per arc φ, therefore

$\frac{1}{\varphi}\ \frac{n_\theta}{N}$ is the relative duration per arc unity, and

$\frac{2\pi}{\varphi}\ \frac{n_\theta}{N} = r\ \frac{n_\theta}{N}$ is the relative duration per arc 2π; and since $a = \frac{1}{r}$ (1) becomes

$$r\,\frac{n_\theta}{N} = 1 + r\left\{R_1 \cos(\theta - \alpha_1) + R_2 \cos(2\theta - \alpha_2) + R_3 \cos(3\theta - \alpha_3) + \&c.\right\}$$

or writing c_1 for $r R_1$, c_2 for $r R_2$, &c., &c.

$$r\,\frac{n_\theta}{N} = 1 + c_1 \cos(\theta - \alpha_1) + c_2 \cos(2\theta - \alpha_2) + c_3 \cos(3\theta - \alpha_3) + \&c. \qquad (2)$$

whence the average relative duration per arc 2π is unity, and the average value of the ordinates, $r\,\frac{n_\theta}{N}$, of a curve constructed from equation (2) with the values of θ as abscisæ would be unity. It would be easy to show also that 2 is the maximum limit of c_1, c_2, &c., and that it implies, when reached, that all the observations without exception were from the direction or directions which correspond to the maximum phase of the term.

194. [The sum of the durations of the observed winds in the several particular directions is equal to the total duration of all the winds observed. It may be worth while to show that, the formula (1) being regarded as applicable for every value of θ, but as yielding a value of $\frac{n_\theta}{N}$ which refers only to an infinitesimal arc $d\theta$, the corresponding result still holds good.

Let T be the total duration of all the winds observed, then

since $\frac{1}{\varphi}\ \frac{n_\theta}{N} = \frac{r}{2}\ \frac{n_\theta}{N}$ is the relative duration per unit of arc,

$T\frac{r}{2\pi}\ \frac{n_\theta}{N}$ is the absolute duration per unit of arc, and we have from (1)

$$T\int_0^{2\pi}\left(\frac{r}{2\pi}\ \frac{n_\theta}{N}\right)d\theta = T\int_0^{2\pi}\frac{r}{2\pi}\ a\,d\theta + \frac{Tr}{2\pi}\int_0^{2\pi}\left\{R_1\cos(\theta-\alpha_1) + R_2\cos.(2\theta-\alpha_2) + R_3\cos(3\theta-\alpha_3) + \&c.\right\}d\theta$$

which since the integral of the last term is *zero*

$= T\,r\,a$, and since $r\,a = 1$

$= T$

that is the integral of the elemental durations, taken for infinitesimal arcs all round the compass is equal to the total duration.

Also, dividing by T, $\int_0^{2\pi}\left(\frac{r}{2\pi}\ \frac{n}{N}\right)d\theta = 1$ or the excess of the area enclosed by the curve of relative duration on the positive side of the axis of abscisæ above that enclosed on the negative side is *unity*.]

195. If now on calculating the coefficients of the expression (2) from observations made at successive hours of the day, or in successive months, and on comparing coefficients of corresponding terms for one hour, or one month, with those of the preceding and following hours or months, we find that a definite law of progression binds together the coefficients of all hours, or all months, we may infer that the coefficients of intermediate times would follow the same progression, and thus we may extend our knowledge of the coefficients, which in strictness is limited to such as refer to momentary intervals about the times of observation, to embrace the whole range of the day or year, as the case may be; hence it would be a legitimate procedure to convert relative durations into absolute durations by multiplying by the corresponding total duration.

196. The treatment of observations of calm and of winds described as too variable to be classed under any one division of the compass will be different, according as the notion of relative frequency or that of relative duration is to be elucidated. In the former case "calms and variables" would form distinct classes of observations, additional to the classification by divisions of the compass, but in the latter it would be convenient that the extreme directions of a variable wind should be noted, and the occurrence be allotted in equal fractional parts to all the divisions of the compass into which the direction enters in passing from one extreme to the other; that is to say, if three divisions were entered, that one-third of an occurrence should be allotted to each of the three divisions. In both cases omitted observations should be taken no account of; and, in regard to relative duration, variable winds, the limits of which are not recorded, should be treated in the same way. But every observation of calm must have the same time attributed to it as every direction observation, although it is inadmissible, by reason of the fundamental assumption that the duration is a function of the direction, to put it in a separate class. The least objectionable procedure seems to be to include calms in the total number N, and disregard them in the rest of the process, except by retaining the value unity of $r\,a$; this is equivalent to allotting the constant fraction $\frac{1}{r}$ to every division of the compass for every occurrence of a calm, an

allotment that does not affect the relative values of the coefficients c_1, $_2c$, &c.; indeed, it affects the coefficients in no other way than by including the duration of calms in the total duration of all winds, and so attributing any preponderances of different winds to the actual times in which they were observed. In the following reductions, calms and variable winds have been treated in the manner just described; and although for some years the observations are all allotted to the eight principal points of the compass, yet they have been classed indiscriminately with other years' observations, and the whole body treated together, as is clearly legitimate, so long as we seek only the coefficients of early terms of the formula (2); the number allotted to the intermediate directions in those years was, of course, *zero*.

197. *Annual variation.*—The observations of direction of the wind taken at the five stations at each of the hours 9.30 a.m. and 3.30 p.m. have been grouped together in months, each group including the observations of all the years for a particular month, giving the following results:—

TABLE 120.

SHOWING the NUMBER of TIMES on which the WIND was observed, at 9.30 a.m. and 3.30 p.m., to BLOW from each DIFFERENT DIRECTION at each STATION in each MONTH.

BELGAUM.

Direction.	AT 9.30 A.M.												AT 3.30 P.M.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
N.	13	33	50	54	29	4		4	7	46	16	11	9	12	16	13	7				3	28	21	7
N.N.E.			2	6		1				1				2	1								1	
N.E.	68	79	106	92	28	6	1	7	7	62	109	66	60	79	40	37	4	1	1		5	68	110	100
E.N.E.	4	12	8	11	2			1	1	9	2	2	4·5	8	2	3					1	2	2	
E.	162	103	78	53	11	3	1	2	5	114	232	232	173·5	104	80	32	6	1		3	2	113	233	243
E.S.E.	15	15	4	6		1		1		12	24	16	11	4	1	2						6	13	11
S.E.	135	82	42	24	6	5			1	34	57	111	87	50	30	18	4		1		4	23	33	53
S.S.E.	10	3	4	2						3	5	7	3	4	1	1				1		1	2	2
S.	29	25	20	20	12	8		2	3	35	12	6	26	23	17	16	7	5	1		3	43	18	9
S.S.W.	1			1		10	5	1					2				1	7	8	6	1		1	
S.W.	29	31	50	65	64	156	191	109	78	29	8	10	53	76	123	135	114	167	191	106	83	55	7	23
W.S.W.	0		1		4	19	40	57	23	2	1		1	1	3	7	15	29	45	44·5	23	8		3
W.	23	52	84	81	265	269	238	316	305	101	8	8	34	84	167	212	333	268	237	356·5	350	117	14	5
W.N.W.		2	2	4	12	6	12	8	17	1				1	1	2	10	5	2	1	7	2		
N.W.		15	28	33	55	11		8	27	47	3	3	4	10	25	11	22	4	1	4	8	14	5	2
N.N.W.		1	1	3	8				2							2								
Calm	38	26	47	55	31	9	6	11	34	59	33	24	59	21	20	19	4	4	8	5	20	45	49	38
Sums	527	479	527	510	527	508	494	527	510	525	510	496	527	479	527	510	527	491	495	527	510	525	509	496

TABLE 121.

POONA.

Direction.	At 9.30 A.M.												At 3.30 P.M.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
N.	54	57	96	100	70	10	3	9	37	56	14	29	56	66	107	140	116	26	1	10	36	75	19	26
N.N.E.	8	7	8	4	5				3	14	16	6	11	13	11	10	3	4	1	1	6	9	16	3
N.E.	25	38	29	31	18	4	2	2	7	46	61	29	31	39	50	36	16	3	1	4	11	65	61	36
E.N.E.	20	22	7	3	1	1		1		22	51	38	18	21	5	11	2	2			5	25	54	31
E.	91	40	30	17	3	2			3	70	168	136	83	33	21	15	9	1			2	72	171	141
E.S.E.	28	13	5	5	1	1			1	21	47	58	27	16	5	3	1	1				17	34	52
S.E.	84	31	26	22	2	7		1	4	56	100	107	93	41	25	25	4	10		4		61	100	109
S.S.E.	28	9	7	8	4	2			1	16	15	20	30	16	7	3		0			1	18	18	22
S.	38	15	10	14	12	6	11	8	5	21	13	12	40	25	19	13	8	8	16	10	5	17	19	14
S.S.W.	13	4	4	2	4	10		1	6	7	2	2	14	5	4	3	2	7			3	7	3	2
S.W.	30	39	30	32	36	116	112	96	74	26	9	17	32	26	33	24	31	156	123	100	76	26	8	18
W.S.W.	17	14	12	8	28	86	112	98	51	21	3		21	15	20	17	19	50	93	94	44	14	0	1
W.	45	65	99	76	135	165	216	233	159	54	5	10	32	60	84	53	96	116	204	193	149	34	4	10
W.N.W.	4	25	35	49	53	24	27	27	55	23	0	16	5	12	31	26	46	35	26	48	71	15	1	14
N.W.	81	77	104	109	138	43	35	42	93	60	4	16	26	72	82	92	130	46	56	55	94	49		15
N.N.W.	11	18	25	30	17	3	4	9	11	14	2		8	21	23	39	44	15	1	8	7	23	2	1
Calm																								
Sums	527	474	527	510	527	480	522	527	510	527	510	496	527	481	527	510	527	480	522	527	510	527	510	495

TABLE 122.

BOMBAY.

Direction.	At 9.30 A.M.												At 3.30 P.M.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
N.	66	52	54	25	5	3	3	6	13	31	24	42	16	39	2	4	1		1	3	3	13	6	22
N.N.E		1																						
N.E.	263	230	119	51	6	7	3	9	28	217	314	331	3			2		3	1	1		4	20	8
E.N.E.											1	6												
E.	75	65	43	24	3	7	9	3	33	74	88	80									1	1	2	3
E.S.E.																								
S.E.	24	25	55	51	17	66	13	21	75	86	40	17	1	1			2	12	2		2	5	4	6
S.S.E.																1								
S.	1	2	15	29	19	50	10	20	30	26	7	3	2			1		28	15	6	10	3	4	
S.S.W.																								
S.W.		1	19	71	145	213	253	231	112	28	1	2	15	13	35	46	109	243	265	215	133	46	16	18
W.S.W.						4	1		5												10			
W.	8	5	6	38	115	80	185	159	124	8	7	3	73	68	75	108	180	130	180	194	196	115	106	63
W.N.W.									1						2						3	1	5	8
N.W.	48	70	162	180	176	56	25	38	87	47	22	25	331	335	362	313	97	72	37	68	153	324	342	384
N.N.W.									2												2		1	
Calm	7	5	3	6	3	2		1	3	2	2	3												
Sums	492	456	476	475	489	488	502	488	513	519	506	512	491	456	476	475	490	488	501	487	513	517	506	512

TABLE 123.

DEESA.

Direction.	At 9.30 A.M.												At 3.30 P.M.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
N.	88	65	40	35	5	2	2	5	9	40	50	85	70	58	30	20	3	2	4	3	10	24	68	84
N.N.E.	45	23	21	12	4			2	3	17	18	33	34	22	6	3	1	1		1	10	10	23	21
N.E.	106	100	59	17		5		2	14	55	88	103	28	23	14	3		9	4	3	13	43	52	56
E.N.E.	24	18	13	6	1		1	0	0	10	59	21	1		1		1	1·5	1	1	1	7	9	4
E.	26	22	33	7		5	3	1	5	26	64	42	4	6	3	1		2	3	1	2	13	18	10
E.S.E.	7	10	6	10		3	1	1	2	18	24	27	1	1	2			3·5	1	2		5	7	7
S.E.	31	18	23	18	7	20	11	6	24	33	40	34	23	7	6	2	3	26	9	3	20	28	35	15
S.S.E.	4	2	11	4	3	7	2	7	2	9	2	11	2	4	3		1	5	5	3	3	10	5	9
S.	3	4	13	25	61	80	49	30	32	15	6	7	15	7	11	13	19	62	45	36	36	21	12	9
S.S.W.	2	4	13	29	101	91	85	90	31	10	2	2	4	9	22	21	60	93	109	69	44	29	12	11
S.W.	5	18	27	44	141	179	202	174	104	35	14	10	28	58	78	92	177	194	203	221	116	58	25	31
W.S.W.	3	4	8	18	33	22	28	34	34	12	5		6	15·5	15	50	61	23	27	33	43	28	9	7
W.	15	33	62	82	74	55	47	50	69	37	9	6	58	71·5	136	124	122	51	36	45	61	48	27	24
W.N.W.	10	13	30	33	25	6	7	16	33	23	3	1	32	25	42	49	26	6	7	12	25	24	17	21
N.W.	40	62	79	75	16	5	10	13	61	53	37	30	81	86	65	58	13	10	2	15	33	62	65	82
N.N.W.	10	7	14	12	2			0	5	21	12	8	25	18	16	11	3	3			7	6	12	22
Calm	46	37	31	39	21	26	40	51	48	51	29	45	53	30	33	19	4	14	36	38	52	41	66	50
Sums	465	440	483	466	494	506	488	482	476	465	462	465	465	441	483	466	494	506	492	491	476	457	462	463

TABLE 124.

KURRACHEE.

Direction.	At 9.30 A.M.												At 3.30 P.M.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
N.	38	36·5	34	37	25	14·5	13	13	2	15	26	18	29	21	14	15·5	4	2	4	7	4	15	36	24
N.N.E.	22	12·5	10	4		0·5		1	1	17	27	24	4	2	2			1			2	5	3	3
N.E.	108	61	30	18	5	2	3	3	4	13	76	103	71	20	6	3	1		4	1	1	7	36	61
E.N.E.	10	8	4	1			2		1	2	2	12	5	1									5	8
E.	144	60	26	9	1	3	1	1	5	17	78	128	83	37	7	2		2			3	4	45	69
E.S.E.	4	3	5	3		1				2	3	2	3	2	2			1				1	1	3
S.E.	20	21	10	6	1	4	1		1	6	8	10	19	15	5				3	2	3	5	7	21
S.S.E.						1·5				1	1		1	4	1					1				4
S.	4	11	6	7	11	7·5		4	2	7	7	9	17	7	5	6	9	20	9	3	1	10	12	13
S.S.W.		2	4	14	17	16	14	8	11	22	7	2	17	23	18	18	16	18	17	10	17	29	17	19
S.W.	3	15	34	68·5	79	93	75	64	58	48	9	7	67	49	82	97	106	126	106	102	115	97	66	57
W.S.W.	2	5	15	14·5	37·5	30·5	43	41·5	32	32	4	0	8	14	27	38·5	44·5	29·5	37	55	50	37	16	9·5
W.	21	48	139	173·5	247·5	238·5	213	201	196	129·5	61	23	89	156	225·5	229·5	273·5	238·5	224	203·5	190·5	198·5	134	98·5
W.N.W.	3	17	19	15·5	12	17	20	35·5	51	25·5	7	2	7	14	15·5	13	8	17	28	26·5	38·5	20·5	9	2
N.W.	26	47	71	90	73	61	129	136	119	60	33	10	33	43	56	82	59	54	92	113	83	55	49	29
N.N.W.	5	9	5	9	7	3	2	1	8	17	6	4	3	8	7	3·5	4				2	7		1
Calm	55	68	67	40	11	12	11	18	19	30	95	80	9	8	6	2	2	1	3	3		3	14	12
Sums	465	424	479	510	527	510	527	527	510	494	450	434	465	424	479	510	527	510	527	527	510	494	450	434

198. The coefficients and angles of formula (2), as representing the annual variations of relative duration of different winds, and calculated from the numbers in Tables 120 to 124, are as follows:—

TABLE 125.

Month.	AT 9.30 A.M.																			
	BELGAUM.				POONA.				BOMBAY.				DEESA.				KURRACHEE.			
	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
January	1·13	109 5	·59	198 44	·47	115 28	·31	231 38	1·44	41 38	·78	95 8	1·04	26 19	·40	47 3	1·19	58 27	·60	146 35
February	·64	93 35	·48	177 37	·27	336 15	·31	217 14	1·67	49 51	·60	96 39	·87	9 54	·25	113 30	·49	11 46	·32	174 39
March	·31	42 24	·50	138 16	·90	316 21	·40	252 28	·79	10 10	·34	283 38	·54	328 40	·20	203 58	·95	290 21	·60	186 39
April	·27	0 0	·48	123 ·1	1·00	316 13	·48	272 23	·59	301 48	·45	266 11	·78	278 52	·21	219 6	1·25	279 41	·57	183 0
May	1·27	275 53	·91	174 59	1·36	297 42	·55	229 24	1·32	270 0	·43	208 33	1·48	228 1	·79	82 4	1·56	270 22	·88	188 30
June	1·64	253 20	1·24	148 53	1·59	257 38	1·04	151 58	1·22	227 0	·44	110 6	1·30	198 51	·93	72 32	1·60	264 37	·97	167 32
July	1·80	250 34	1·41	141 55	1·75	258 49	1·25	155 29	1·60	244 4	1·13	129 37	1·53	221 17	1·06	81 20	1·62	274 37	·89	185 46
August	1·74	259 43	1·46	158 21	1·70	262 35	1·19	161 25	1·48	243 57	·93	127 7	1·46	227 13	·95	85 47	1·62	277 26	·90	194 11
September	1·60	266 4	1·30	169 23	1·45	278 21	·70	186 31	·70	248 12	·47	189 52	1·00	250 7	·31	135 0	1·61	277 8	·99	196 59
October	·25	78 44	·57	166 56	·25	26 34	·34	215 32	·98	63 57	·44	103 6	·13	315 0	·31	189 10	1·13	276 7	·52	173 25
November	1·50	86 34	·90	171 4	1·44	94 46	·77	188 14	1·55	54 15	1·04	104 26	·96	54 19	·35	136 10	·48	8 28	·48	145 59
December	1·46	96 41	·95	167 17	1·16	100·55	·81	213 53	1·64	48 13	1·16	98 25	1·00	42 58	·30	48 59	1·20	65 22	·74	135 0
Means for Year	·25	244 26	·86	160 56	·50	281 32	·55	190 29	·27	353 40	·48	120 21	·31	255 4	·39	91 28	·78	289 22	·66	135 40

TABLE 125—*continued.*

Month.	AT 3.30 P.M.																			
	BELGAUM.				POONA.				BOMBAY.				DEESA.				KURRACHEE.			
	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
January	·87	110 6	·69	174 13	·53	118 1	·26	249 27	1·82	308 4	1·44	261 12	·72	352 47	·29	303 41	·13	298 37	·68	141 36
February	·29	123 41	·77	150 26	·38	341 34	·22	264 48	1·80	310 15	1·43	264 46	·95	301 41	·08	246 48	·92	268 45	·77	173 15
March	·59	246 2	·93	153 43	·82	321 27	·17	283 14	1·80	303 26	1·41	257 20	1·15	274 29	·43	176 1	1·50	266 11	·96	169 10
April	1·01	252 39	·88	139 37	·99	333 42	·45	316 47	1·72	298 3	1·20	249 0	1·37	267 55	·62	162 9	1·63	259 23	·92	168 41
May	1·70	261 12	·86	154 37	1·34	312 35	·51	273 22	1·64	278 46	·82	206 53	1·64	240 47	·99	113 44	1·72	262 18	1·13	164 7
June	1·80	251 52	1·39	146 46	1·45	236 13	·71	139 34	1·54	245 26	·78	122 28	1·10	231 59	·97	76 15	1·65	257 44	1·00	158 50
July	1·79	249 2	1·39	139 5	1·71	259 33	1·12	156 52	1·71	245 50	1·12	125 32	1·57	218 16	1·19	77 50	1·64	265 26	·94	172 43
August	1·84	258 23	1·56	160 31	1·64	264 44	1·05	164·30	1·68	254 48	·97	141 15	1·52	226 20	1·10	86 53	1·64	268 36	·91	175 36
September	1·72	262 45	1·47	165 52	1·45	280 46	·70	186 31	1·59	270 43	·75	185 20	1·07	240 47	·52	101 6	1·62	264 19	·95	178 52
October	·09	144 28	·73	154 8	·46	44 7	·16	235 18	1·64	298 27	1·14	251 5	·45	273 49	·17	118 4	1·48	262 38	·81	162 1
November	1·83	84 25	·91	160 46	1·38	90 25	·69	194 14	1·72	307 52	1·30	252 7	·51	352 11	·17	336 22	·74	276 10	·68	154 56
December	1·37	88 45	1·01	166 15	1·17	102 51	·78	214 6	1·73	309 51	1·45	262 29	·75	338 12	·34	344 45	·18	278 11	·72	144 5
Means for Year	·53	243 26	1·03	155 25	·47	300 58	·38	193 40	1·55	287·16	·76	233 35	·81	259 15	·38	96 1	1·23	264 55	·85	163 41

199. If from the intersection of two rectangular axes representing the directions north—upward, east—to the right, south—downward, and west—to the left, we set off a straight line equal to c_1, and in the direction α_1 reckoned from north by a right-handed rotation, it will mark the direction and magnitude of the maximum relative duration expressed by the second

term of (2); and if this be done for each month, and the extremities of the lines of successive months be joined by straight lines, the curve formed will represent the annual variation of the amplitude and direction of maximum of the relative durations expressed by the term in question; and if similar constructions be made with respect to c_2 and α_2, a similar interpretation may be applied, providing the directions are marked in the following manner: north and south—upward, east and west—downward, north-east and south-west—to the right, and south-east and north-west—to the left.

200. The observations taken at each hour of one day, in each month of each year, afford also materials for obtaining the annual variation of the relative duration coefficients, in the manner of paragraphs 193 to 196. The coefficients will in this case refer to the mean of the 24 hours in the same way that the coefficients of Table 125 refer to the hours 9.30 a.m. and 3.30 p.m.

Tables 126 to 130 show the number of times on which, in the 24 consecutive hours' observations in each month, the wind is reported to have blown at each station from each different direction.

TABLE 126.

BELGAUM.

Direction.	At any of the 24 Hours of the Day.											
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
N.	9	14	8	29	4					7	6	18
N.N.E.	1	1									1	
N.E.	16	52	28	25	10				1	54	58	75
E.N.E.	6	3	4	7						2	1	4
E.	114	83	76	15						121	197	144
E.S.E.	1	3	5	2						22	7	15
S.E.	58	30	23	8	8					28	13	26
S.S.E.	3			2						1	2	1
S.	30	2	11	17	14	3			5	46	1	2
S.S.W.		1		2		4	7			1		1
S.W.	36	18	46	64	94	135	142	73	61	18	4	14
W.S.W.		9		8	13	32	52	48	53	4		
W.	103	122	169	176	211	186	183	258	261	52	15	3
W.N.W.	2	5	1	9	5				1		1	
N.W.	3	14	13	13	24			5	2	4	6	9
N.N.W.		3		7	1							
Calm	2											
Sums	384	360	384	384	384	360	384	384	384	360	312	312

TABLE 127.

POONA.

Direction.	At any of the 24 Hours of the Day.											
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
N.	52	42	155	88	48	16	2	10	28	51	4	61
N.N.E.	4	1	2	5	1					12	4	3
N.E.	9	46	39	24	27				16	38	6	27
E.N.E.	15	13	8	1						22	28	34
E.	82	76	31	21		5				32	195	122
E.S.E.	4	21	12							48	68	76
S.E.	70	44	24	19					8	126	103	71
S.S.E.	19	2	4	7					1	14	12	17
S.	38	8	20	34	1		11	6	4	21	2	5
S.S.W.	7	22	11	2	1				1	2	8	
S.W.	46	16	20	26	44	118	72	84	88	17	18	30
W.S.W.	29	3	19	18	35	101	103	95	37	13	4	
W.	35	41	36	101	104	178	238	220	147	45	28	10
W.N.W.		29	31	34	56	10	31	30	62			
N.W.	22	48	52	68	153	46	22	59	112	38		
N.N.W.		44	16	32	10	6	1			1		
Calm												
Sums	432	456	480	480	480	480	480	504	504	480	480	456

TABLE 128.

BOMBAY.

Direction.	At any of the 24 Hours of the Day.											
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
N.	76	55	34	28	1	3	1	1	21	16	57	53
N.N.E.		1	2							9	2	
N.E.	105	57	37	13	3	4	1	3	17	106	128	133
E.N.E.		6	1							7	17	22
E.	22	16	7	11	2	11	5		26	59	37	16
E.S.E.									10			3
S.E.	13	24	13	5	9	21	4	5	50	36	25	9
S.S.E.							1		1			
S.	7	3	8	11	25	48	4	16	27	16	3	3
S.S.W.		1		3	2		4					
S.W.	11	8	29	40	95	237	244	173	66	17	4	3
W.S.W.					1	5	33	38				
W.	17	29	42	84	96	68	139	180	117	19	20	31
W.N.W.	2	1		8			4	3	23	2	3	7
N.W.	184	248	261	245	220	59	16	37	86	146	144	164
N.N.W.	6	5	12		1				2	15	3	5
Calm	13	2	10	3	1				10	8	13	7
Sums	456	456	456	456	456	456	456	456	456	456	456	456

TABLE 129.
DEESA.

Direction.	At any of the 24 Hours of the Day.											
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
N.	60	42	43	4		4	15	5	5	21	63	69
N.N.E.	7	25	12			1			1	12	18	38
N.E.	46	58	18	3		1	3		9	41	50	58
E.N.E.	3	8							7	15	17	6
E.	4	14	12			2			3	29	49	18
E.S.E.		1	5			1	1		2	26	5	4
S.E.	19	6	8		1	28	6	11	14	25	29	9
S.S.E.	2	1	7	1	6	2	4	6	4	1	1	
S.	5		4	14	34	21	16	26	27	13	2	2
S.S.W.	1	7	12	23	47	79	82	81	20	1	1	3
S.W.	24	17	11	78	168	191	147	153	72	7	10	10
W.S.W.	7	2	7	15	35	15	9	10	40	9	2	4
W.	23	48	58	79	29	16	18	10	36	13	4	3
W.N.W.	5	20	23	20	2	1	3		3	4	8	24
N.W.	73	44	38	24	9		8	2	35	21	21	28
N.N.W.	22	3	5	1		1			2	3	16	3
Calm	59	40	49	74	53	21	48	80	80	71	64	57
Sums - -	360	336	312	336	384	384	360	384	360	312	360	336

TABLE 130.
KURRACHEE.

Direction.	At any of the 24 Hours of the Day.											
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
N.	23	29	10	8	5	4	16	14	13	32	26	18
N.N.E.	11	6	2				2	8		12	33	5
N.E.	46	27	16	1			2	5	20	17	46	54
E.N.E.	7	1	8				3		1	2	1	4
E.	83	55	8	4		1				29	37	74
E.S.E.	5	1	4							2	1	6
S.E.	16	8	12						4	5	5	17
S.S.E.	1		1				1			2	1	2
S.	10	4	12	1	1	3	1	1	6	11	8	10
S.S.W.	1	10	12	19	20	4	5	1	2	4	2	3
S.W.	33	25	50	67	62	15	61	50	55	40	42	27
W.S.W.	2	2	9	21	20	31	20	48	27	30	7	4
W.	30	61	119	177	202	216	166	177	157	45	61	45
W.N.W.	6	13	4	16	15	13	19	19	51	7	1	4
N.W.	3	36	63	47	35	39	64	70	41	55	6	14
N.N.W.	3	3	4	1	1	3	5	11	7	8	4	7
Calm	32	55	50	22	23	7	19	4	24	59	79	66
Sums - -	312	336	384	384	384	336	384	408	408	360	360	360

201. The coefficients and angles of formula (2), as representing the annual variation of the average relative duration of different winds for the 24 hours of the day, calculated from the numbers in Tables 126 to 130, are as follows:—

TABLE 131.

Month.	At any of the 24 Hours of the Day.																			
	BELGAUM.				POONA.				BOMBAY.				DEESA.				KURRACHEE.			
	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
January	·44	149 56	·95	182 25	·42	144 47	·19	201 15	1·18	348 13	·43	298 56	·80	337 16	·33	328 44	·53	71 13	·67	142 17
February	·16	333 26	1·12	171 48	·40	20 44	·42	227	1·26	332 0	·90	273 49	·78	343 39	·24	114 27	·37	321 35	·49	173 1
March	·49	255 58	1·22	171 5	·76	344 41	·37	334	1·33	316 50	·94	270 40	·69	308 32	·21	226 58	·92	271 15	·57	177 59
April	1·05	267 49	·88	157 14	·87	305 9	·29	266 3	1·39	302 40	·90	253 11	1·20	250 58	·58	135 0	1·54	265 9	·98	168 48
May	1·59	258 46	1·14	159 30	1·46	297 16	·63	223 4	1·39	280 49	·65	241 28	1·52	224 12	1·10	85 50	1·63	263 40	1·09	167 52
June	1·85	269 48	1·44	141 47	1·66	260 39	1·15	151 26	1·88	238 53	·73	101 0	1·58	214 42	1·22	76 46	1·76	271 57	1·41	182 26
July	1·86	249 14	1·48	139 24	1·81	260 29	1·39	162 51	1·73	242 24	1·30	123 5	1·36	221 25	1·14	71 34	1·50	274 12	·88	179 21
August	1·89	259 21	1·61	160 47	1·74	265 3	1·19	166 26	1·67	250 48	1·09	140 12	1·38	214 23	1·11	69 27	1·59	276 30	·96	178 48
September	1·88	259 35	1·61	161 54	1·46	278 41	·74	190 6	·72	266 49	·61	213 41	·85	237 25	·42	109 17	1·38	274 33	·92	176 53
October	·76	107 43	·78	168 59	·54	106 5	·53	250 12	·74	9 20	·31	238 24	·51	64 26	·22	172 14	·60	294 51	·25	156 30
November	1·51	81 13	1·36	169 51	1·41	109 5	1·21	201 16	1·05	8 12	·12	255 58	·84	36 44	·12	48 22	·29	342 11	·62	112 50
December	1·39	79 15	·94	161 22	1·19	95 20	·62	202 50	1·17	356 5	·15	254 3	·96	11 26	·42	40 9	·33	58 44	·58	152 6
Means for Year	·59	250 1	1·18	161 16	·45	277 36	·57	191 7	86	298 40	·29	216 28	·47	252 43	·46	82 34	·87	277 17	·75	167 38

The figures corresponding to the numbers in this table are numbered 523 to 532.

202. *Diurnal variation.*—The hourly observations of direction of the wind taken at the five stations are as yet so few in number that monthly groups for each hour of the day formed from them would be too meagre to be used for calculating the coefficients of expression (2) for the diurnal variation of relative duration. Under this circumstance they have been put into groups embracing the months June to September, November to January, and February to April, and in one general group for the whole year; the object of the grouping being to contrast the diurnal variations at each station during the monsoon and during the two halves of the dry season, and to compare the variations of corresponding seasons at the different stations. The winds of May and October, which are generally of intermediate character between those of the monsoon and those of the dry season, and insufficient to form separate groups by themselves, have been included only in the general grouping of all the months of the year.

Tables showing the numbers of observations at each hour of the day for the full year and each season, and for each station, would occupy so much space that we subjoin only a specimen table, giving, however, in the table which then follows, the values of the coefficients for every case.

TABLE 132.

SHOWING the NUMBER of TIMES on which the WIND was observed at each Hour of the Day to blow at BELGAUM from each different Direction in the Months February to April of all the Years.

Local Civil Hours	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5
N.	3	3	3	3	2	4	2	5	1		1	1					1	1	3	1	2	5	5	5
N.N.E.																	1							
N.E.	7	4	10	9	9	7	6	10	13	8	5	7	6	1	1	1								1
E.N.E.				1	1	2	5	1	2	1			1											
E.	5	8	8	10	9	9	10	11	9	12	11	7	6	5	5	6	5	7	4	3	5	4	6	9
E.S.E.	1		1	1	2		1	2	2															
S.E.	2	3	1	2	5	11	7	4	4	3	2	4	2				1	1	2	2	1	1	2	1
S.S.E.		1	1		0																			
S.	2	1	1	4	1		3	4	2	1	1			2	1	1	1	1	1	1	1	1		
S.S.W.		1				1					1													
S.W.	6	6	5	5	5	2	2	2	4	7	8	9	7	4	5	9	7	6	9	7	4	4	2	3
W.S.W.		1	2								2		1			1		2	1	2	1	2	1	1
W.	15	13	12	9	9	7	8	4	9	14	15	19	24	34	33	27	29	27	26	28	29	25	26	25
W.N.W.	1	1	1	1		1	1		1						1	1	1	1				2		
N.W.	3	5	1	2	2	3	1	3		1				1	1	1	1	1	1	2	3	2	4	1
N.N.W.	2		1				1	1												1	1	1	1	1
Calm																								

The coefficients and angles of formula (2), as representing the diurnal variation of relative duration of different winds, calculated from the numbers in Table 132, and 19 other similar tables, are as follows :— (See Tables 133 to 137 on pages 166 to 170.)

The last line of Tables 133 to 137 shows the extent of the observations from which the coefficients are derived, and therefore the relative weights of the several sets of independent coefficients.

203. In constructing curves to represent variations of the relative duration coefficients, it is generally more convenient to use the a_1, b_1, a_2, b_2 coefficients rather than their equivalents c_1, α_1, c_2, α_2; and besides, we find that, in constructing curves with 12 points for the annual variations, and 24 points for the diurnal variations, it often happens that the points are so near together as to produce confusion in the figure, and to avoid this we can readily take averages of the a_1, b_1, a_2, b_2 coefficients respectively, and so substitute a single point for a number of points; this substitution seems desirable also in cases where a total absence of system is displayed in the disposition of successive points. Accordingly we have reduced the number of points in the manner shown in the following tables (see Tables 138 to 143, pages 171 to 176), from the numbers in which the curves of figures 533 to 547 and 548 to 587 have been constructed.

204. *Remarks on annual variations.*—The discussion of the annual variation of the a_1, b_1 coefficients of relative duration of the wind we defer until the corresponding results for the Presidency at large are brought together in our next part. For the present we remark that the closed curves of annual variations of the a_1, b_1 coefficients

TABLE 133.

BELGAUM.

Hours.	November to January.				February to April.				June to September.				Year.			
	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
6	1·11	78 35	1·17	164 11	·49	291 22	·68	161 2	1·87	253 53	1·52	149 33	·53	254 39	1·14	157 16
7	1·13	81 52	1·21	168 2	·41	278 20	·73	172 53	1·87	253 13	1·51	148 0	·56	248 0	1·14	162 41
8	1·06	80 48	1·08	162 44	·22	333 26	·89	146 29	1·86	254 41	1·48	150 50	·47	251 34	1·13	154 48
9	1·39	92 53	·96	182 59	·22	65 46	·72	146 19	1·86	253 25	1·48	150 30	·35	229 34	·97	161 56
10	1·55	98 55	·80	198 53	·27	70 12	·82	165 7	1·87	255 9	1·53	152 12	·35	226 10	1·00	166 40
11	1·58	95 13	·87	203 38	·51	79 48	·59	194 45	1·86	256 56	1·50	155 9	·25	216 52	·89	174 14
12	1·68	92 23	1·05	186 2	·57	87 59	·73	175 18	1·86	253 25	1·46	148 10	·25	198 26	·97	163 49
13	1·72	90 20	1·17	186 53	·73	67 19	·35	154 53	1·83	251 52	1·41	145 24	·19	188 58	·90	159 9
14	1·65	97 18	1·08	185 52	·52	76 46	·95	146 39	1·75	252 42	1·33	145 43	·26	204 37	1·07	156 48
15	1·48	98 11	1·01	184 32	·07	146 19	1·20	155 22	1·81	250 58	1·35	145 15	·43	224 4	1·13	155 56
16	1·39	96 12	1·23	186 5	·37	289 18	1·17	153 39	1·85	251 4	1·47	145 14	·51	231 20	1·22	155 19
17	1·27	92 15	1·27	183 36	·47	252 43	1·18	154 18	1·87	255 27	1·54	154 36	·58	246 32	1·26	162 0
18	·85	104 22	1·08	184 14	·75	263 4	1·44	158 25	1·88	255 13	1·54	152 36	·76	248 29	1·31	160 19
19	·60	107 32	1·06	166 21	1·36	264 5	1·58	173 49	1·90	255 58	1·59	153 55	1·00	253 44	1·38	162 13
20	·39	94 24	1·12	164 29	1·39	265 2	1·61	173 35	1·88	253 36	1·53	148 54	1·04	255 2	1·38	160 54
21	·47	106 7	1·10	175 19	1·27	257 43	1·51	164 39	1·88	255 49	1·56	154 6	1·02	252 17	1·36	161 34
22	·42	98 8	1·20	170 23	1·26	263 9	1·38	171 13	1·87	256 42	1·54	156 36	1·02	256 22	1·37	163 25
23	·48	79 9	1·15	155 26	1·17	261 58	1·46	172 9	1·87	254 29	1·52	151 45	·96	255 32	1·34	159 57
0	·46	98 51	1·24	157 10	1·24	259 19	1·18	165 44	1·89	256 51	1·58	156 11	·99	255 58	1·34	160 21
1	·53	70 12	1·20	161 34	1·38	261 42	1·27	172 46	1·89	256 33	1·59	154 43	1·03	258 48	1·35	161 26
2	·57	62 59	1·04	155 39	1·26	272 16	1·32	180 0	1·89	257 8	1·59	156 40	·98	261 13	1·27	161 42
3	·61	64 32	1·07	151 31	1·23	275 37	1·07	179 27	1·89	255 36	1·58	153 16	·95	263 19	1·19	159 54
4	·68	65 42	1·14	150 30	1·06	283 7	1·16	188 24	1·88	254 56	1·57	151 48	·86	223 42	1·22	160 23
5	·72	67 1	·99	151 7	·82	282 41	1·23	175 49	1·88	255 49	1·54	153 46	·80	263 30	1·25	159 49
Means	·97	90 0	1·06	172 52	·54	270 0	1·07	167 32	1·87	254 46	1·51	151 34	·65	250 10	1·19	160 48
Number of Days' Observations	42				47				63				183			

being much greater than those of the a_2, b_2 coefficients, it is appropriate to direct the mind in the first place especially to the consideration of the former variations, thus treating the latter as representing residual phenomena, which may be more effectually investigated after a physical theory shall have been devised to account for the a_1, b_1 variations. At the same time we remark that the a_2, b_2 variations exhibit systematic character, and, in the case of Bombay, a magnitude which it would be improper to overlook. Comparing the relative positions of the yearly points of the a_1, b_1 curves for 9.30 a.m. and 3.30 p.m. with the relative positions for 9.30 a.m. and 3.30 p.m. in the curves (figures 551, 555, 559, 563, and 567) of mean diurnal variations for the year, we see that, although derived from independent series of observations, the direction and amount of the differences are generally the same. Viewing the curves of annual variation of the a_1, b_1 coefficients in Plate XLIV., we can readily imagine the general form of average curves for the hours 9.30 a.m. and 3.30 p.m., and comparing these, station by station, with the curves of Plate LXIII., which have reference to the mean of the 24 hours, we observe a close general likeness. If the fact indicated by this likeness—that the mean annual variation for the mean of the

TABLE 134.

POONA.

Hours.	November to January.				February to April.				June to September.				Year.			
	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
6	·98	102 20	·70	184 54	·77	303 17	·47	302 0	1·64	260 32	1·23	160 6	·58	270 59	·63	186 26
7	·98	99 56	·67	178 17	·78	310 50	·46	307 7	1·65	259 31	1·26	157 31	·56	273 4	·62	180 0
8	1·03	101 12	·72	188 48	·77	311 20	·40	290 14	1·63	260 29	1·25	156 55	·55	272 5	·65	184 24
9	1·08	97 59	·72	184 46	·66	322 26	·47	277 16	1·67	261 23	1·25	159 49	·50	274 34	·65	188 0
10	1·09	103 16	·84	193 42	·81	342 41	·51	277 49	1·64	264 3	1·28	159 52	·41	287 6	·67	193 51
11	1·12	105 2	·78	202 37	·85	344 59	·35	274 54	1·59	263 9	1·02	159 58	·39	284 45	·60	195 25
12	1·15	110 19	·74	214 33	·80	357 8	·18	276 20	1·62	267 53	1·01	166 14	·34	292 45	·54	196 5
13	1·11	106 48	·78	213 29	·71	1 37	·25	274 34	1·56	268 32	1·03	160 41	·34	295 49	·52	193 14
14	1·16	111 43	·75	218 32	·59	4 51	·33	328 44	1·57	269 38	·89	165 2	·32	288 26	·43	198 51
15	1·12	113 8	·66	229 18	·52	357 48	·29	319 11	1·54	265 33	·85	157 4	·32	278 53	·37	203 48
16	1·06	108 47	·66	210 4	·58	4 56	·35	348 22	1·61	266 59	·95	157 23	·37	287 27	·37	189 13
17	·92	114 54	·67	200 51	·56	353 53	·33	313 47	1·68	271 22	1·06	175 41	·44	283 6	·46	195 15
18	·94	115 12	·65	197 53	·65	347 28	·19	325 29	1·70	271 1	1·02	175 31	·47	283 27	·45	189 2
19	·91	114 2	·68	209 13	·64	340 43	·25	338 38	1·92	270 0	1·08	176 49	·50	283 46	·48	195 47
20	·92	108 26	·64	208 11	·66	328 44	·17	239 2	1·72	267 0	1·13	171 52	·56	279 18	·60	194 30
21	·92	107 3	·65	205 23	·62	328 53	·24	209 45	1·72	267 0	1·13	171 52	·56	278 17	·66	193 11
22	·95	107 6	·75	203 30	·60	326 35	·28	247 4	1·67	266 34	1·06	173 29	·53	276 28	·64	196 26
23	·87	108 1	·73	195 11	·54	327 12	·30	235 47	1·66	266 54	1·06	171 20	·53	274 19	·64	190 47
0	·91	105 2	·66	192 20	·49	310 51	·34	233 28	1·67	264 30	1·04	166 38	·54	271 4	·61	188 32
1	·90	106 13	·63	191 51	·56	311 23	·33	226 13	1·68	266 56	1·10	167 59	·56	274 5	·63	186 20
2	·87	111 33	·66	202 17	·52	309 31	·35	222 43	1·69	264 13	1·15	162 21	·58	268 2	·67	185 58
3	·94	111 55	·69	202 7	·48	318 22	·35	222 43	1·67	264 30	1·11	164 50	·54	267 53	·68	187 39
4	·92	109 37	·75	201 48	·45	326 40	·30	216 52	1·70	264 56	1·17	165 8	·53	268 55	·69	184 58
5	·91	112 37	·69	203 58	·51	325 23	·25	226 38	1·68	263 51	1·13	164 7	·54	267 53	·63	184 32
Means	·99	107 42	·69	201 20	·59	333 52	·25	274 34	1·65	265 50	1·08	165 35	·47	277 17	·58	189 57
Number of Days' Observations	57				59				82				238			

24 hours is sensibly the same as the mean of the annual variations for the hours 9.30 a.m. and 3.30 p.m.—could have been presumed apart from the likeness in question, we might then have drawn from the likeness the inference that independent series of observations at the same place lead to results of definite and uniform character, and finding the likeness to hold with respect to separate series of observations at a number of different stations, we are disposed—notwithstanding the presumption being still needed—to place a degree of confidence in such results, as representing real phenomena, that perhaps the mode of educing them may of itself in some minds fail to beget for them.

205. From the large departure from parallelism of form of the 9.30 a.m. and 3.30 p.m. curves for Bombay we draw the conclusion that the diurnal variation of relative duration of different winds must be of very different character or range in different seasons; and so, it will be seen presently, the hourly observations show it to be. At Belgaum there is also a difference in the diurnal variations of different seasons, though of less magnitude than at

TABLE 135.

BOMBAY.

Hours.	November to January.				February to April.				June to September.				Year.			
	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
6	1·44	35 7	·70	74 10	1·09	356 51	·59	310 11	1·28	239 2	·71	136 9	·49	334 29	·20	107 32
7	1·46	42 13	·73	92 21	1·00	12 39	·33	335 42	1·20	238 18	·65	140 39	·39	352 42	·29	123 41
8	1·39	44 8	·70	94 54	·85	34 26	·24	27 39	1·24	240 57	·68	136 12	·32	0 0	·38	116 34
9	1·43	48 24	·74	106 29	·84	33 53	·06	288 26	1·12	237 43	·67	130 8	·29	14 2	·41	120 58
10	1·43	51 32	·76	179 5	·63	333 26	·33	301 16	1·23	232 17	·93	115 28	·19	325 30	·45	109 39
11	1·39	46 27	·65	84 44	·51	316 35	·22	287 43	1·24	233 30	·89	113 7	·22	302 17	·43	110 33
12	·94	16 7	·26	141 20	1·27	295 34	·84	245 16	1·31	236 33	·82	120 0	·68	282 48	·34	115 14
13	1·05	328 17	·57	267 59	1·64	302 49	1·12	249 37	1·42	245 25	·76	130 12	1·09	286 27	·44	217 39
14	1·24	314 1	·89	253 37	1·67	303 47	1·18	249 44	1·43	243 26	·84	121 26	1·18	285 13	·50	216 52
15	1·42	312 26	1·00	248 18	1·75	306 9	1·32	252 48	1·51	253 29	·81	138 29	1·33	288 2	·63	221 47
16	1·56	308 46	1·11	249 27	1·82	302 12	1·43	252 57	1·55	252 44	·84	135 29	1·42	286 23	·72	228 22
17	1·58	315 0	1·18	267 34	1·80	306 26	1·55	261 49	1·62	252 1	·98	139 9	1·41	289 20	·68	240 47
18	1·73	317 6	1·43	274 50	1·84	306 30	1·52	259 21	1·53	253 20	·81	140 1	1·48	291 52	·76	246 48
19	1·71	318 19	1·46	275 54	1·74	310 6	1·35	267 27	1·49	249 8	·93	133 41	1·41	292 2	·71	251 3
20	1·64	323 25	1·37	279 15	1·77	310 53	1·45	266 27	1·55	251 55	1·06	140 45	1·40	294 33	·66	248 50
21	1·53	330 15	1·06	284 10	1·77	309 58	1·40	265 4	1·52	251 34	1·13	142 56	1·31	294 48	·58	247 11
22	1·53	334 6	1·01	296 34	1·61	310 13	1·16	268 2	1·48	246 56	1·03	138 8	1·19	294 51	·42	239 45
23	1·40	345 34	·69	230 52	1·65	309 6	1·24	263 30	1·39	246 45	·83	134 31	1·07	296 34	·35	248 30
0	1·21	351 0	·41	229 2	1·56	308 47	1·29	266 27	1·35	253 11	·59	150 23	·98	300 46	·41	254 37
1	1·23	8 51	·34	8 22	1·47	315 0	1·09	267 22	1·30	251 9	·55	152 3	·87	306 36	·29	243 26
2	1·25	16 16	·30	70 21	1·49	314 11	1·08	312 48	1·18	248 39	·62	157 10	·82	310 4	·27	225 0
3	1·29	20 58	·44	76 54	1·42	321 36	·81	270 0	1·23	245 31	·55	141 40	·76	315 24	·19	205 12
4	1·37	29 45	·59	95 48	1·22	325 1	·70	291 2	1·28	245 38	·60	141 3	·68	315 0	·17	151 56
5	1·37	28 15	·59	89 2	1·10	328 46	·57	296 7	1·19	244 43	·50	143 8	·59	319 49	·15	126 52
Means	1·12	356 56	·21	280 47	1·30	316 34	·90	266 11	1·36	246 5	·77	135 32	·85	298 40	·29	216 28
Number of Days' Observations	57				57				76				228			

Bombay, but the hours of observation, 9.30 a.m. and 3.30 p.m., are—unlike the same hours at Bombay—affected similarly in the same season, and so the two annual variation curves for Belgaum are nearly alike. The two curves for Poona are alike for a different reason, viz., because the diurnal variation is of very small range all through the year. The unlikeness of those for Deesa and Kurrachee arises in the same way as in those for Bombay.

206. *Remarks on diurnal variation.*—We learn from figures 548 to 587 that the diurnal variation of the monsoon months is at all the stations of very small extent: during the dry season it is largest at Bombay, next in extent at Belgaum, next at Kurrachee, then at Deesa, and least at Poona, where it is very small. At the coast stations, Bombay and Kurrachee, and at the low station, Deesa, the principal features of the diurnal variations of the dry season are land and sea breezes blowing from seaward during the afternoon hours, with maximum excesses of westerly component an hour or two before sunset; and blowing from landward during the forenoon hours, with maximum excesses of easterly component

TABLE 136.

DEESA.

Hours.	November to January.				February to April.				June to September.				Year.			
	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
6	1·20	29 34	·54	53 58	·59	289 39	·40	178 34	1·07	220 5	·92	66 14	·26	256 30	·51	79 48
7	1·15	28 8	·34	60 28	·46	286 28	·31	146 49	1·11	218 25	1·01	64 42	·29	249 41	·54	82 29
8	1·35	36 17	·62	62 12	·28	302 0	·31	137 36	1·31	222 13	1·03	72 27	·25	243 26	·64	80 59
9	1·38	39 42	·51	56 56	·31	333 26	·08	299 45	1·09	237 20	·98	75 15	·16	248 12	·51	69 27
10	1·14	39 41	·60	53 8	·26	263 25	·19	207 54	1·23	224 20	·76	71 34	·23	223 16	·46	66 48
11	·82	54 23	·42	85 55	·61	281 16	·18	119 22	1·44	226 58	1·08	85 46	·48	234 19	·60	92 52
12	·81	52 34	·63	86 22	·63	264 34	·20	98 32	1·45	224 43	1·08	90 32	·55	226 28	·67	88 17
13	·49	20 17	·51	62 56	·82	255 58	·16	71 34	1·47	223 21	·95	85 11	·72	234 5	·57	80 52
14	·74	340 49	·21	12 7	·92	286 16	·26	130 22	1·43	219 2	1·01	79 42	·75	245 30	·52	81 5
15	·67	323 28	·21	272 44	1·18	282 16	·42	166 18	1·42	216 9	·97	73 15	·81	250 26	·42	84 34
16	·66	328 0	·40	316 0	1·07	287 25	·40	175 43	1·33	220 25	1·01	80 21	·77	254 53	·42	81 52
17	·86	333 44	·32	321 20	·98	286 2	·47	151 47	1·40	217 27	1·10	79 0	·76	253 57	·52	85 26
18	·78	331 48	·37	292 23	1·09	289 16	·41	164 37	1·26	212 3	·95	66 24	·74	252 4	·36	82 6
19	·96	337 26	·31	312 24	·97	288 4	·48	164 13	1·22	218 0	1·03	75 26	·67	260 32	·37	88 27
20	·85	337 57	·24	326 59	·85	295 3	·41	150 57	1·24	221 24	·86	79 20	·62	257 58	·41	90 0
21	·78	354 9	·38	655 29	·74	292 23	·42	135 58	1·20	214 29	·93	72 32	·54	252 54	·47	82 43
22	·82	5 34	·46	339 35	·73	302 10	·30	150 1	1·34	219 32	1·04	78 22	·52	253 18	·49	81 52
23	·85	356 38	·45	318 35	·77	292 13	·47	114 57	1·32	218 31	1·02	79 48	·57	253 47	·53	81 15
0	·74	350 13	·32	347 17	·77	292 13	·47	114 57	1·28	220 53	1·07	77 39	·60	252 28	·59	85 9
1	·60	5 43	·19	306 15	·71	308 9	·34	139 46	1·33	221 21	1·04	77 50	·50	246 30	·48	85 14
2	·73	4 42	·17	10 0	·66	322 26	·26	122 28	1·28	218 40	·95	79 3	·44	249 54	·52	83 25
3	·87	3 18	·20	336 2	·72	319 29	·24	112 15	1·19	217 9	·82	73 46	·39	256 40	·45	74 24
4	·82	9 15	·25	336 8	·69	323 18	·24	92 23	1·10	216 8	·78	69 42	·31	258 41	·43	66 27
5	·99	11 5	·21	343 18	·60	331 19	·07	81 52	1·17	218 3	·77	70 9	·27	254 56	·36	63 26
Means	·79	9 28	·23	15 15	·69	292 7	·27	141 1	1·27	220 13	·96	76 6	·50	249 3	·49	80 32
Number of Days' Observations	44				41				62				176			

an hour or two after sunrise; and the hours intervening between the maxima of westerly and easterly components have excesses of north component, and the remaining hours have excesses of south component durations: thus the curves are all formed by a circulation in a right-handed direction round the point which represents the mean duration and direction of the 24 hours. The variation in the east and west direction is generally greater than that in the north and south direction, but in the period February to April the two variations become of nearly equal extent both at Deesa and Kurrachee.

207. The characteristics of the diurnal variation just described are traceable also in the Bombay curve for the monsoon months, but not so either at Deesa or Kurrachee; there is system, however, in the curve of Deesa, but with a circulation in the reverse direction to that of the dry season's curves. The right-handed rotation about the mean point for the day is present in all the curves, for the dry season, of Belgaum and Poona: an east and west variation also forms the principal feature of the closed curves, but it does not correspond to

TABLE 137.

KURRACHEE.

Hours.	November to January.				February to April				June to September.				Year.			
	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2
		° ′		° ′		° ′		° ′		° ′		° ′		° ′		
6	1·14	36 8	·36	147 39	·60	301 39	·79	178 25	1·36	281 53	·95	187 16	·58	302 19	·74	170 54
7	1·11	73 51	·47	145 18	·66	292 17	·87	177 22	1·51	282 39	·90	185 5	·64	294 58	·76	173 8
8	·91	59 28	·51	115 34	·64	292 58	1·00	172 31	1·55	281 32	·96	185 21	·72	293 43	·79	170 32
9	·85	65 50	·52	139 38	·64	296 58	·81	179 18	1·50	273 18	1·10	181 34	·70	285 50	·84	175 8
10	·74	65 10	·99	149 50	·56	282 19	·72	144 5	1·59	270 22	1·18	182 55	·72	278 1	·87	167 4
11	·61	94 41	1·04	172 48	·54	249 34	·60	179 2	1·60	266 25	1 14	169 53	·71	261 4	·89	170 1
12	·37	120 42	·59	127 27	·71	239 27	·55	165 12	1·63	269 18	1·21	175 17	·83	259 38	·80	164 5
13	·32	185 21	·54	132 46	1·05	241 29	·57	155 14	1·62	271 25	1·07	174 41	1·01	256 48	·79	161 0
14	·28	225 0	·66	126 21	1·24	249 40	·70	140 50	1·57	268 10	1 05	166 46	1·14	257 18	·81	147 5
15	·69	239 19	1·00	116 49	1·20	259 54	·71	171 52	1·56	267 25	·99	168 55	1·24	253 46	·83	158 49
16	·78	241 48	·87	126 16	1·26	262 43	·76	170 54	1·64	271 3	1·09	175 48	1·31	262 7	·88	158 47
17	·72	237 24	·92	150 39	1·42	259 52	·85	168 26	1·61	267 31	·96	171 2	1·37	260 45	·95	164 48
18	·76	305 22	·93	169 25	1·47	267 16	1·02	174 24	1·63	276 20	1·02	183 56	1·35	270 51	·99	175 23
19	·48	285 47	·70	157 27	1·44	270 0	·80	167 42	1·60	270 22	1·08	170 58	1·31	270 53	·93	168 40
20	·34	322 8	·69	153 26	1·37	271 40	·89	169 42	1·62	272 49	1·12	180 31	1·20	275 17	·88	172 5
21	·43	341 8	·52	149 2	1·29	277 7	·86	176 40	1·59	274 43	1·14	179 0	1·12	279 13	·83	173 8
22	·44	0 0	·55	152 58	1·21	278 4	·86	188 20	1·57	276 56	1·08	182 7	1·04	282 10	·80	175 13
23	·17	346 46	·49	105 28	1·15	282 6	·60	195 25	1·55	276 40	1·10	182 36	1·01	281 25	·63	176 22
0	·54	41 58	·43	139 41	·93	284 20	·52	195 38	1·42	276 53	·94	180 0	·84	288 0	·61	178 7
1	·55	38 20	·20	84 6	·91	275 39	·51	170 55	1·52	278 43	·95	182 25	·85	285 40	·56	170 13
2	·91	52 7	·51	114 32	·59	281 8	·51	175 31	1·51	274 10	1·03	177 47	·75	291 48	·64	167 17
3	·97	50 25	·67	106 32	·78	288 40	·51	175 45	1·48	278 11	·81	186 20	·74	300 2	·50	164 51
4	1·06	40 47	·57	103 4	·67	300 23	·41	184 11	1·57	278 48	·95	191 33	·76	305 22	·49	173 7
5	1·02	41 49	·62	92 46	·65	316 15	·36	170 16	1·56	280 22	·94	193 35	·75	308 32	·46	167 28
Means	·32	43 44	·59	135 40	·92	278 7	·69	172 24	1·55	274 26	1·03	179 27	·91	276 58	·76	168 37
Number of Days' Observations	48				46				64				184			

the land and sea breezes of the coast stations. Here the westerly component is in excess during the night hours—from sunset to sunrise—and the easterly component during the day hours, with maximum about or a little after noon: thus the excess winds, above the mean wind of the day, blow from the interior of India while the sun is above the horizon, and towards the interior when the sun is below the horizon. Hence we infer that the sphere of action of the land and sea breezes — the theory of which requires winds of essentially different character from those described—does not reach with sensible effect the stations of Belgaum and Poona, and probably does not extend eastward of the Western Ghauts; also that the winds of the western border of the Deccan plateau belong—in respect of their diurnal variations—to a distinct system from those of stations below the Ghauts. Of other noteworthy points we may mention the remarkable difference of range of the diurnal variations of Belgaum and Poona; the lateness of the early morning movements at Poona in the period February to April; and the reversal at Poona, as at Deesa, of the direction of rotation of the monsoon curve as compared with the dry season's curves.

Table 138.

Of Equivalents a_1, b_1, a_2, b_2, to the Coefficients and Angles c_1, α_1, c_2, α_2, given in Table 125, representing Annual Variations.

At 9.30 A.M.

Month.	Belgaum.				Poona.				Bombay.				Deesa.				Kurrachee.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
January	−·37	+1·07	−0·56	−·19	−·20	+0·42	−0·22	−·21	+1·08	+0·96	−·07	+0·78	+0·93	+0·46						
February	−·04	+0·64	−0·48	+·02	+·25	−0·11			+1·08	+1·28	−·07	+0·60	+0·86	+0·15	−·10	+0·23	+·48	+0·10	−·32	+·03
March	+·23	+0·21	−0·31	+·36	+·65	−0·62	−0·05	−·43	+0·73	+0·14	+·08	−0·38	+0·46	−0·28	−·17	−0·10	+·83	−0·89	−·58	−·05
April	+·27	0·00			+·72	−0·69			+0·31	−0·50	−·03	−0·45	+0·12	−0·77			+·21	−1·23		
May	+·13	−1·26	−0·91	+·08	+·63	−1·20	−0·36	−·42	0·00	−1·32	−·39	−0·17	−0·99	−1·10	+·11	+0·79	−·07	−1·57		
June	−·47	−1·57	−1·08	+·75	−·34	−1·55	−0·92	+·49	−0·83	−0·89	−·15	+0·41	−1·23	−0·42	+·28	+0·89			−·90	·00
July	−·60	−1·70			−·84	−1·72	−1·14	+·52	−0·70	−1·44	−·64	+0·80	−1·15	−1·01	+·16	+1·05				
August	−·31	−1·71	−1·36	+·54	−·22	−1·69	−1·13	+·38	−0·65	−1·33			−0·99	−1·07	+·07	+0·95	+·18	−1·61	−·91	−·25
September	−·11	−1·60	−1·28	+·24	+·21	−1·43	−0·70	−·08	−0·26	−0·65	−·46	−0·08	−0·34	−0·04						
October	+·07	+0·24	−0·56	+·13	+·22	+0·11	−0·28	−·20	+0·43	+0·88	−·10	+0·43	+0·09	−0·09	−·26	+0·14	+·12	−1·12	−·52	+·06
November	+·09	+1·50	−0·91	+·17	−·12	+1·44	−0·71	−·28	+0·90	+1·25	−·26	+1·01	+0·56	+0·78			+·47	+0·07		
December	−·17	+1·45			−·22	+1·14			+1·09	+1·22	−·17	+1·15	+0·73	+0·68	+·23	+0·26	+·56	+1·05	−·47	+·37
Means for year	−·11	−0·23	−0·81	+·28	+·10	−0·19	−·54	−0·10	+0·27	−0·03	−·24	+0·41	−0·08	−0·30	−·01	+0·39	+·26	−0·74	−·66	+·05

At 3.30 P.M.

Month.	Belgaum.				Poona.				Bombay.				Dees				Kurrachee.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
January	−·30	+0·82	−0·69	+·07	−·25	+0·47			+1·12	−1·43			+0·71	−0·09	+·16	−0·24				
February	−·16	+0·24			+·36	−0·12	−0·02	−·21	+1·16	−1·37	−·21	−1·41	+0·50	−0·81	−·03	−0·07	−·02	−0·92	−0·76	+·09
March	−·24	−0·54	−0·74	+·43	+·64	−0·51			+0·99	−1·50			+0·09	−1·15	−·48	+0·03			−0·92	+·18
April	−·30	−0·96			+·89	−0·44	+0·33	−·31	+0·81	−1·52	−·43	−1·12	−0·05	−1·37	−·59	+0·19	−·24	−1·60		
May	−·26	−1·68			+·91	−0·99	+0·03	−·51	+0·25	−1·62	−·73	−0·37	−0·80	−1·43	−·40	+0·91			−1·09	+·81
June	−·56	−1·71	−1·10	+·83	+·44	−1·38	−0·54	+·46	−0·64	−1·40	−·42	+0·66	−0·68	−0·87	+·23	+0·94			−0·93	+·36
July	−·64	−1·67			−·31	−1·68	−1·03	+·41	−0·70	−1·56	−·65	+0·91	−1·23	−0·97	+·25	+1·16				
August	−·37	−1·80	−1·45	+·44	−·15	−1·63	−1·01	+·28	−0·44	−1·62	−·76	+0·61	−1·05	−1·10	+·06	+1·10	−·13	−1·59	−0·92	+·13
September	−·23	−1·70			+·27	−1·42	−0·70	−·08	+0·02	−1·59	−·75	−0·07	−0·52	−0·93	−·10	+0·51				
October	−·07	+0·05	−0·66	+·32	+·33	+0·32	−0·09	−·13	+0·78	−1·44	−·37	−1·08	+0·03	−0·45	−·08	+0·15			−0·69	+·27
November	+·19	+1·82	−0·92	+·27	−·01	+1·38	−0·66	−·30	+1·04	−1·37	−·40	−1·24	+0·51	−0·07	+·16	−0·07	+·08	−0·74		
December	+·03	+1·37			−·26	+1·14			+1·11	−1·33			+0·70	−0·28	+·33	−0·09	+·03	−0·14	−0·35	+·42
Means for year	−·24	−0·48	−0·94	+·43	+·24	−0·40	−0·37	−·09	+0·46	−1·48	−·45	−0·61	−0·15	−0·79	−·04	+0·38	−·11	−1·23	−0·82	+·24

The curves constructed from the numbers in this table are numbered 533 to 547.

TABLES 139 to 143.

Of Equivalents a_1, b_1, a_2, b_2, to the Coefficients and Angles c_1, α_1, c_2, α_2, given in Tables 133 to 138, representing Diurnal Variations.

TABLE 139.

BELGAUM.

Hours.	November to January.				February to April.				June to September.				Year.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
6	+·22	+1·(	−1·15	+·28	+·18	−0·46	−0·68	+·15								
7	+·16	+2·12			+·06	−0·41							−·17	−0·49	−1·05	+·42
8	+·17	+1·05	−1·03	+·32	+·20	−0·10	−0·67	+·44	−·51	−1·79	−1·31	+·73				
9	−·07	+1·33	−0·96	−·05	+·09	−0·20							−·23	−0·26	−0·94	+·26
10	−·24	+1···	−0·76	−·26	+·09	+0·25	−0·79	+·21								
11	−·14	+1·57	−0·80	−·35	+·09	+0·50	−0·65	−·04	−·42	−1·81			−·22	−0·11	−0·89	+·19
12	−·07	+1·68	−1·04	−·11	+·02	+0·57			−·53	−1·78	−1·20	+·78			−0·88	+·29
13	−·01	+1·72	−1·10	−·14	+·28	+0·67	−0·32	+·15	−·57	−1·74			−·19	−0·03		
14	−·21	+1·64	−1·07	−·11	+·12	+0·51	−0·79	+·52	−·52	−1·67	−1·10	+·76	−·24	−0·11		
15	−·21	+1·46	−1·01	−·08	−·06	+0·04			−·59	−1·71			−·31	−0·30	−1·04	+·46
16	−·15	+1·38	−1·22	−·3	−·19	−0·32	−1·07	+·51	−·60	−1·75	−1·21	+·84	−·32	−0·40		
17	−·05	+1·27	−1·27	−·08	−·14	−0·45							−·23	−0·53		
18	−·21	+0·82	−1·08	−·08	−·09	−0·74	−1·34	+·53					−·28	−0·71		
19	−·18	+0·57	−1·03	+·25	−·14	−1·35										
20	−·03	+0·39			−·12	−1·38	−1·54	+·25	−·48	−1·82						
21	−·13	+0·45	−1·12	+·20	−·27	−1·24							−·26	−0·97	−1·26	+·43
22	−·06	+0·42			−·15	−1·25										
23	+·09	+0·47			−·20	−1·15					−1·40	+·69				
0	−·07	+0·45	−1·08	+·43	−·23	−1·22	−1·29	+·15								
1	+·18	+0·50			−·20	−1·37			−·43	−1·84			−·20	−1·01		
2	+·26	+0·51			+·05	−1·26							−·15	−0·97		
3	+·30	+0·63			+·12	−1·22							−·11	−0·94		
4	+·28	+0·62	−0·90	+·46	+·24	−1·03	−1·15	−·02	−·47	−1·82			−·09	−0·86	−1·15	+·42
5	+·28	+0·66			+·18	−0·80							−·09	−0·79		
Means	·00	+0·97	−1·04	+·15	·00	−0·54	−1·04	+·23	−·49	−1·80	−1·33	+·72	−·22	−0·61	−1·12	+·29

208. *Comparison of the coefficients of relative duration of the wind derived from personal observations, with coefficients derived from instrumental registrations, and of the variations of the latter, with variations of the wind measured mechanically, that is, by its direction and velocity.*—The observations taken at Bombay together with the registrations of the Robinson-Beckley anemometer afford means of comparing the results of observations made by an observer standing on the ground, in a position not wholly unobstructed, with the results yielded by an instrument exposed completely in all directions, and raised 53 feet above the ground level; and afford also a convenient opportunity of exhibiting the likenesses and differences between variations of relative duration, and variations of mechanical movement of the same winds,—phenomena which, though of perfectly distinct kinds, are closely related to each other. For these comparisons, we shall make use of the seven years' registrations of direction of the wind made by Robinson's anemometer between June 1867 and May 1874, besides the curves of relative duration coefficients and of velocity of the wind already given. The coefficients derived from the anemometer records of direction are shown in Table 144.

TABLE 140.
POONA.

Hours.	November to January.				February to April.				June to September.				Year.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
6							+·26	−·38							−·63	−·04
7	−·19	+·98	−·70	−·05	+·48	−·60			−·27	−1·62						
8							+·14	−·38			−1·17	+·45	+·03	−·52		
9	−·15	+1·07			+·52	−·40	+·06	−·49								
10	−·27	+1·07	−·82	−·20	+·79	−·23			−·18	−1·60			+·11	−·38	−·62	−·14
11			−·72	−·30			+·03	−·35								
12					+·80	−·04	+·02	−·21			−0·97	+·31			−·51	−·13
13	−·38	+1·07	−·62	−·44	+·71	+·02							+·13	−·31		
14									−·06	−1·56					−·37	−·14
15	−·39	+1·01	−·48	−·50	+·56	·00	+·27	−·17			−0·79	+·29	+·05	−·32		
16			−·57	−·33									+·11	−·39		
17									+·03	−1·69	−1·06	+·08			−·43	−·09
18	−·39	+·84			+·61	−·17	+·19	−·10					+·11	−·47		
19			−·60	−·27					·00	−1·92						
20							−·15	−·13			−1·07	+·12				
21					+·51	−·32			−·09	−1·69			+·08	−·54		
22	−·27	+·87	−·69	−·24			−·14	−·25							−·61	−·14
23																
0			−·63	−·13			−·21	−·25			−1·04	+·23	+·03	−·54		
1																
2					+·36	−·34	−·26	−·24							−·66	−·07
3	−·33	+·85	−·64	−·27					−·15	−1·67	−1·10	+·31				
4							−·4	−·18					·00	−·55		
5							−·17	−·18								
Means	−·30	+·94	−·64	−·25	+·53	−·26	+·02	−·25	−·12	−1·65	−1·05	+·27	+·06	−·47	−·57	−·10

The curves that we have constructed from these numbers for comparison are annual variation curves from the monthly values, shown in the last line, of c_1, α_1, c_2, α_2, and the diurnal variation curves from the values given in the last four sets of columns; the former curves are numbered 590 and 591, and the latter 597 to 600 and 609 to 612. The personal observation curves 588 and 589, and 593 to 596, are repetitions of figs. 525 and 530, and 556 to 559, respectively.

209. Comparing figures 593 to 596 with figures 597 to 600 respectively — curves which represent variations of the same phenomenon differently observed—the principal points that strike the reader are, the greater regularity of flow, and somewhat wider range, of the anemometer curves, showing a decided advantage of instrumental records over personal observations, providing the instrument be a high-class one, and its exposure unobstructed. The two sets of curves are in fair general agreement, though the diurnal movements of the wind as exhibited by the anemometer are persistently somewhat in advance of those observed from the ground level. In the two corresponding sets of a_2, b_2 curves (or in their equivalents the c_2, α_2 curves) the greater regularity of the anemometer curves is as striking, and the greater range more so, than in the a_1, b_1 curves. The similarity of the modifications of the variations with change of season in the two sets of curves is distinct; the general agreement is fair, but with the same lagging behind of the

TABLE 141.
BOMBAY.

Hours.	November to January.				February to April.				June to September.				Year.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
6	+1·18	+0·83	+·19	+0·67	+1·09	−0·06	+·38	−0·45					+·44	−0·21	−·06	+·19
7	+1·08	+0·98	−·04	+0·71	+0·98	+0·22	+·34	−0·13	−·62	−1·04	−·48	+·47	+·39	−0·05	−·16	+·24
8	+1·00	+0·97			+0·70	+0·48	+·21	+0·11					+·32	0·00	−·17	+·34
9	+0·95	+1·07	−·16	+0·73	+0·70	+0·47							+·28	+0·07	−·21	+·35
10	+0·89	+1·12			+0·56	−0·28	+·02	−0·18					+·16	−0·11	−·15	+·42
11	+0·96	+1·01	+·06	+0·65	+0·37	−0·35			−·74	−1·02			+·12	−0·19	−·15	+·40
12	+0·90	+0·26	−·20	+0·16	+0·55	−1·15	−·35	−0·76			−·42	+·73	+·15	−0·66	−·33	+·07
13	+0·89	−0·55	−·02	−0·57	+0·89	−1·38	−·39	−1·05	−·61	−1·28			+·31	−1·05	−·35	−·27
14	+0·86	−0·89	−·25	−0·85	+0·93	−1·39	−·41	−1·11					+·31	−1·14	−·40	−·30
15	+0·96	−1·05	−·37	−0·93	+1·03	−1·41	−·39	−1·26					+·41	−1·26	−·47	−·42
16	+0·98	−1·22	−·39	−1·04	+0·97	−1·54	−·42	−1·37			−·63	+·55	+·40	−1·36	−·48	−·54
17	+1·12	−1·12	−·05	−1·18	+1·07	−1·45	−·25	−1·51					+·47	−1·34	−·33	−·59
18	+1·27	−1·18	+·12	−1·42	+1·10	−1·48			−·47	−1·46			+·55	−1·37	−·30	−·70
19	+1·28	−1·14	+·15	−1·45	+1·12	−1·33							+·53	−1·31	−·23	−·67
20	+1·32	−0·98	+·22	−1·35	+1·16	−1·34	−·09	−1·40					+·58	−1·27	−·24	−·62
21	+1·33	−0·76	+·26	−1·03	+1·14	−1·36					−·74	+·66	+·55	−1·19	−·27	−·51
22	+1·38	−0·67	+·45	−0·90	+1·04	−1·23			−·56	−1·32			+·50	−1·08	−·21	−·36
23	+1·36	−0·35	+·45	−0·52	+1·04	−1·28	−·09	−1·23					+·48	−0·96	−·13	−·33
24	+1·20	−0·19	+·35	−0·21	+0·98	−1·22			−·40	−1·26			+·50	−0·84	−·11	−·40
1	+1·22	+0·19	+·34	+0·05	+1·04	−1·04	−·05	−1·09			−·52	+·26	+·52	−0·70	−·13	−·26
2	+1·20	+0·35	+·10	+0·28	+1·04	−1·07	+·05	−0·97					+·53	−0·63	−·19	−·19
3	+1·20	+0·46	+·10	+0·43	+1·11	−0·88	·00	−0·81	−·49	−1·12			+·52	−0·55	−·17	−·08
4	+1·19	+0·68	−·02	+·59	+1·00	−0·70	+·25	−0·65			−·43	+·34	+·48	−0·48	−·15	+·08
5	+1·21	+0·65			+0·94	−0·57	+·25	−0·51					+·45	−0·38	−·09	+·12
Means	+1·12	−0·06	+·04	−0·21	+0·94	−0·89	−·06	−0·89	−·55	−1·23	−·55	+·54	+·41	−0·75	−·23	−·17

curves representing the ground level observations that appeared in the a_1, b_1 curves. In the annual variation curves, figures 588 to 591, there is a remarkable similarity throughout, except that the a_2, b_2, anemometer curve is on a scale, in the vertical direction, which is about twice as great as that of the corresponding personal observation curve. This exception means that whilst the preponderance of N.E. and S.W. winds over N.W. and S.E. winds, or *vice versâ*, varies in the same way and to the same extent from month to month, both at a height of 53 feet and near the ground, the preponderance of N. and S. winds over E. and W. winds, or *vice versâ*, although varying in the same way, does so at a height of 53 feet to double the extent of the variation near the ground; in other words, this particular component of the wind variation increases, in the particular case, as we ascend from near the ground. There is another evidence of greater preponderance of prevailing winds at the upper than at the lower position, in the greater length of the *radii vectores* for September and October in fig. 590 than in fig. 588; but a part of this greater length is doubtless due to the greater frequency with which calms are recorded, at this season, by the observer than by the instrument.

210. We come now to the comparison of the variations of the direction and velocity of the wind with variations of the relative duration coefficients a_1, b_1, both being derived from the records of the anemometer: this, in effect, is a comparison of the motion of the air, measured mechanically, with the results of the application of Lambert's formula to records of direction of the wind only, a comparison which—considering the large extent to which

TABLE 142.

DEESA.

Hours.	November to January.				February to April.				June to September.				Year.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
6	+1·04	+·59			+·20	−0·56	−·40	+·01			+·40	+0·87	−·03	−·26	+·08	+·51
7	+1·01	+·54			+·13	−0·44	−·24	+·19								
8	+1·09	+·80	+·28	+·44	+·15	−0·24					+·28	+0·96			+·10	+·63
9	+1·06	+·88			+·28	−0·14	−·06	−·08	−0·81	−0·89			−·11	−·15	+·18	+·45
10	+0·88	+·73			−·03	−0·26					+·24	+0·72				
11	+0·48	+·67			+·15	−0·59			−0·98	−1·05			−·33	−·39		
12	+0·49	+·64	+·10	+·50	−·06	−0·63	−·02	+·18	−1·08	−1·02	+·05	+1·04			+·04	+·58
13	+0·46	+·17			−·20	−0·80			−1·07	−1·01			−·42	−·58		
14	+0·70	−·23	+·22	+·05	−·06	−0·92	−·17	+·20	−1·11	−0·90			−·31	−·68		
15	+0·54	−·40	+·01	−·21	+·25	−1·15			−1·15	−0·84	+·21	+1·00	−·27	−·76		
16	+0·56	−·35			+·32	−1·02										
17	+0·77	−·38			+·27	−0·94	−·41	+·13					−·21	−·72	+·04	+·42
18	+0·69	−·37	+·22	−·24	+·36	−1·03					+·38	+0·87				
19	+0·89	−·37			+·30	−0·92							−·12	−·63		
20	+0·79	−·32			+·36	−0·77					+·23	+0·91				
21	+0·78	−·08			+·28	−0·68			−1·01	−0·80						
22	+0·82	+·08	+·36	−·14	+·39	−0·62							−·16	−·53		
23	+0·85	−·05			+·29	−0·71	−·24	+·30							+·06	+·51
0	+0·74	−·01			+·29	−0·71					+·20	+1·00				
1	+0·60	+·06			+·44	−0·56										
2	+0·73	+·06			+·52	−0·40	−·11	+·22					−·15	−·42		
3	+0·87	+·05	+·17	−·06	+·55	−0·47										
4	+0·88	+·14			+·55	−0·41	−·01	+·24			+·25	+0·75			+·15	+·38
5	+0·97	+·19			+·53	−0·29	+·01	+·07	−0·89	−0·69						
Means	+0·78	+·13	+·22	+·06	+·26	−0·63	−·21	+·17	−0·97	−0·82	+·23	+0·93	−·18	−·47	+·08	+·48

Lambert's formula has been used, for lack of reliable movement records—will, doubtless, have some interest for that not inconsiderable class of meteorologists which is in the habit of reasoning upon data yielded by Lambert's formula, as if those data were mechanical measures. In such reasoning, if a mechanical significance be at all attributed to the data, it proceeds on the assumption that all winds blow with equal strength. Taking the velocity curves, figures 601 to 604* as standards of comparison for figures 597 to 600 respectively, we see the effect of this assumption in the tendency to equalization of the *radii vectores* of the latter curves. Allowing for this equalization, the general character of the two sets of curves is in other respects surprisingly like, both in the separate seasons and in the mean curves for the year; and the same may be said with respect to the curves 592 (constructed from the numbers at the foot of Table 76) and 590 of annual variations. It is undoubtedly legitimate, therefore, in the case of the winds of Bombay, to draw qualitative inferences from data furnished by Lambert's formula; and if this be so, with respect to a station whose wind system is of very variable character, we may conclude that it is probably so generally; and accordingly, in our discussion, in the next part, of the winds of the Presidency, we have—without losing sight of the distinct nature of the phenomena—made use of the a_1, b_1 coefficients of relative duration, as representing not only the prevailing

* See paragraph 211*a*.

TABLE 143.
KURRACHEE.

Hours.	November to January.				February to April.				June to September.				Year.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
6	+·46	+1·04			+·31	−0·51	−·70	·00			−0·91	−·13	+·31	−0·49	−·61	+·09
7	+·31	+1·07	−·33	+·31	+·25	−0·61										
8	+·46	+0·78			+·25	−0·59	−·89	+·06					+·25	−0·64		
9	+·35	+0·78			+·29	−0·57					−1·14	−·04				
10	+·31	+0·67	−·94	+·31	+·12	−0·55							+·10	−0·71	−·86	+·13
11	−·05	+0·61			−·19	−0·51					−1·16	+·15	−·11	−0·70		
12	−·19	+0·32			−·36	−0·61	−·55	+·25					−·15	−0·82	−·74	+·21
13	−·32	−0·03	−·37	+·47	−·50	−0·92							−·23	−0·98		
14	−·20	−0·20			−·48	−1·16							−·25	−1·11	−·69	+·43
15	−·35	−0·59	−·49	+·82	−·21	−1·18			+·01	−1·60			−·28	−1·21		
16	−·37	−0·69			−·16	−1·25	−·76	+·13			−1·03	+·12	−·20	−1·32	−·82	+·32
17	−·39	−0·61			−·25	−1·40										
18	+·44	−0·62	−·74	+·30	−·07	−1·47							+·02	−1·33	−·94	+·17
19	+·13	−0·46			·00	−1·44	−·89	+·14								
20	+·27	−0·21			+·04	−1·37							+·11	−1·19		
21	+·41	−0·14	−·47	+·26	+·16	−1·28	−·86	·00					+·18	−1·11	−·83	+·09
22	+·44	0·00			+·17	−1·20							+·21	−1·00		
23	+·17	−0·04	−·23	+·37	+·24	−1·12	−·54	−·15			−1·05	−·01				
0	+·40	+0·36			+·23	−0·90							+·24	−0·81	−·60	+·07
1	+·43	+0·34			+·09	−0·91										
2	+·56	+0·72			+·17	−0·87			+·22	−1·50			+·28	−0·70		
3	+·62	+0·75	−·11	+·51	+·25	−0·74	−·46	+·03					+·37	−0·64		
4	+·80	+0·69			+·34	−0·58							+·44	−0·62		
5	+·76	+0·68			+·47	−0·45							+·47	−0·59		
Means	+·23	+0·22	−·43	+·41	+·05	−0·92	−·67	+·09	+·12	−1·55	−1·03	+·01	+·11	−0·90	−·74	+·15

The curves constructed from the numbers in Tables 139 to 143 are numbered 548 to 587.

direction of the wind, but, with some rough degree of approximation, its relative strength also. It must, however, always be kept in mind that quantitative deductions from the a_1, b_1 duration coefficients, as representing the strength of the wind, can only be accepted provisionally, a caution which is even more needful in comparing the coefficients of different stations than in comparing the coefficients of different hours or seasons at the same station.

211. From the numbers in Table 144 have been constructed curves representing the diurnal variations of the relative duration coefficients for each month of the year, the c_1, α curves being numbered 685 to 696, and the c_2, α_2 curves 697 to 708; and from the same numbers, curves representing the annual variations for each hour of the day, the c_1, α_1 curves being numbered 637 to 660, and the c_2, α_2 curves 661 to 684. The first of these sets of curves is for comparison with the corresponding diagrams (figs. 106 to 110 and 99 to 105) of diurnal variations of the mechanical motion of the wind; and, for comparison with the second set of c_1, α_1 curves, we have constructed also curves (figs. 613 to 636) of annual variation, for each hour of the day, of the mechanical motion of the wind. In the duration curves the equalization of the *radii vectores*, already remarked upon, is a general mark of contrast with the corresponding mechanical motion curves; but the general similarity of corresponding curves is, nevertheless, of an order which strongly supports the conclusion drawn in the last paragraph.

TABLE 144.

SHOWING the RELATIVE DURATION COEFFICIENTS derived from SEVEN YEARS' REGISTRATIONS of DIRECTION of the WIND at BOMBAY, made by ROBINSON'S ANEMOMETER.

Bombay Civil Hours.	January.				February.				March.				April.				May.				June.			
	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2	c_1	α_1	c_2	α_2
		° ′		° ′		° ′		° ′		° ′		° ′		°		°		° ′		° ′		° ′		° ′
0	1·68	5 25	1·19	1 56	1·54	353 37	1·07	337 2	1·38	324 38	0·97	302 9	1·46	309 51	0·96	288 33	1·37	273 11	0·59	204 42	1·30	187 25	0·93	136 0
1	1·61	9 3	1·10	0 44	1·49	1 12	0·97	343 20	1·37	328 53	1·00	310 50	1·37	316 20	0·92	306 3	1·38	274 33	0·52	204 45	1·28	232 10	0·91	138 44
2	1·59	13 39	1·05	7 20	1·48	3 50	0·96	347 20	1·34	336 42	0·98	317 27	1·25	321 19	0·78	320 32	1·32	276 8	0·47	216 4	1·22	229 58	0·88	136 48
3	1·57	18 28	1·00	11 57	1·50	7 59	1·00	354 21	1·28	350 3	0·98	338 2	1·08	332 8	0·74	338 35	1·27	278 23	0·37	214 53	1·20	231 50	0·82	151 41
4	1·61	22 7	1·00	24 13	1·50	13 9	0·98	3 48	1·24	4 7	0·92	354 7	1·02	345 33	0·74	354 9	1·11	281 18	0·23	187 51	1·17	233 28	0·69	144 13
5	1·63	24 39	1·03	33 21	1·53	18 33	0·99	15 20	1·22	17 20	0·75	6 47	0·84	359 27	0·68	5 9	1·00	281 18	0·22	178 57	1·04	229 29	0·71	149 20
6	1·61	31 57	0·93	47 35	1·56	26 1	0·90	32 24	1·26	28 31	0·74	18 36	0·83	9 30	0·61	6 18	0·92	277 26	0·17	149 23	1·02	228 39	0·66	155 36
7	1·61	36 46	0·87	61 40	1·60	33 56	0·90	56 23	1·26	34 20	0·64	27 56	0·70	27 35	0·59	11 33	0·82	272 48	0·17	189 57	1·00	225 41	0·58	149 2
8	1·63	41 32	0·91	77 14	1·61	41 58	0·85	80 41	1·18	36 42	0·42	17 55	0·47	10 13	0·54	327 37	0·96	267 45	0·39	218 22	1·06	225 9	0·61	149 40
9	1·57	43 35	0·75	85 6	1·58	45 42	0·78	96 25	0·88	19 45	0·32	286 14	0·51	300 26	0·63	276 47	1·26	264 42	0·54	210 1	1·21	229 45	0·58	149 41
10	1·40	38 10	0·36	101 22	1·17	28 31	0·17	171 32	0·93	322 23	0·73	258 7	1·38	282 42	0·83	231 18	1·63	264 6	0·85	189 3	1·44	235 29	0·75	129 6
11	1·10	3 24	0·47	268 36	1·22	331 32	0·94	257 17	1·55	299 34	1·20	244 24	1·74	283 57	1·17	215 39	1·73	270 30	1·12	187 32	1·57	241 3	0·93	132 7
12	1·34	321 25	1·02	267 21	1·72	307 34	1·39	251 23	1·81	294 32	1·42	234 10	1·80	285 52	1·33	215 43	1·80	272 7	1·34	188 19	1·62	243 25	0·95	136 47
13	1·72	311 2	1·33	262 37	1·87	304 34	1·60	249 59	1·86	296 31	1·52	237 0	1·84	288 47	1·48	220 41	1·82	274 30	1·40	193 31	1·65	245 30	1·04	139 39
14	1·81	309 19	1·46	261 50	1·89	305 58	1·64	254 41	1·87	299 2	1·56	240 45	1·86	290 21	1·50	222 52	1·85	276 28	1·48	196 13	1·67	246 41	1·08	143 9
15	1·81	312 55	1·45	268 37	1·88	309 54	1·61	262 43	1·89	301 35	1·60	245 25	1·85	292 41	1·53	228 8	1·84	276 52	1·46	196 55	1·69	248 14	1·12	145 47
16	1·83	318 3	1·50	279 13	1·86	314 35	1·55	272 40	1·88	304 19	1·57	251 5	1·89	295 7	1·60	231 35	1·83	278 12	1·42	200 24	1·67	248 31	1·14	145 42
17	1·82	323 3	1·51	290 51	1·88	317 51	1·59	278 38	1·87	305 25	1·55	254 15	1·87	295 59	1·55	234 43	1·80	277 50	1·34	199 59	1·63	248 28	1·13	145 5
18	1·89	328 28	1·66	300 43	1·86	322 0	1·61	288 52	1·83	308 49	1·48	262 18	1·79	297 54	1·46	241 35	1·77	277 56	1·30	200 24	1·60	246 59	1·09	143 37
19	1·91	330 53	1·72	304 55	1·85	325 49	1·63	296 24	1·76	310 48	1·37	271 20	1·73	299 90	1·40	248 57	1·69	278 38	1·13	202 29	1·54	241 34	1·06	136 25
20	1·89	338 4	1·67	318 35	1·83	329 18	1·57	302 27	1·64	312 29	1·22	280 27	1·61	303 14	1·24	255 8	1·59	275 36	1·02	204 8	1·47	240 11	0·98	140 19
21	1·84	345 52	1·55	333 17	1·71	338 8	1·34	316 11	1·50	315 0	1·09	290 48	1·59	305 15	1·18	262 19	1·56	275 17	0·89	201 47	1·45	237 32	0·97	141 33
22	1·81	354 14	1·44	347 38	1·61	346 8	1·20	328 8	1·43	318 15	1·00	296 25	1·50	306 18	1·07	270 45	1·54	273 52	0·80	197 53	1·39	234 20	0·96	139 0
23	1·76	0 14	1·36	355 55	1·58	350 18	1·17	331 53	1·44	319 7	0·95	295 46	1·50	307 0	1·00	272 52	1·46	273 31	0·76	202 8	1·36	232 49	0·96	133 4
Resultant for 24 Hours	1·43	355 7	0·72	329 16	1·39	345 55	0·74	302 24	1·28	324 10	0·80	278 26	1·28	305 34	0·77	257 20	1·47	274 58	0·82	198 14	·37	238 13	0·89	141 13

TABLE 144—*continued.*

Bombay Civil Hours.	July.				August.				September.				October.				November.				December.			
	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2
		° ′		°		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′		° ′
0	1·77	246 47	1·52	140 46	1·72	256 37	1·44	152 10	1·28	271 31	0·83	186 29	1·02	14 1	0·44	348 20	1·43	41 31	0·60	68 30	1·54	26 23	0·88	31 24
1	1·77	248 35	1·48	142 12	1·74	257 0	1·49	153 9	1·21	273 45	0·87	190 58	0·95	24 54	0·27	350 32	1·49	48 48	0·70	88 57	1·54	35 46	0·77	53 11
2	1·79	248 55	1·51	143 45	1·72	256 7	1·48	152 49	1·13	269 27	0·78	181 42	0·93	33 20	0·21	19 35	1·55	52 39	0·88	101 59	1·57	43 18	0·76	76 46
3	1·75	248 39	1·41	144 17	1·71	256 28	1·46	154 35	1·06	268 16	0·78	180 40	1·05	40 49	0·31	56 28	1·64	52 13	1·12	100 47	1·64	42 8	0·91	77 45
4	1·75	250 5	1·50	147 20	1·68	257 29	1·45	155 24	0·91	263 12	0·72	178 30	1·15	40 58	0·54	62 9	1·68	53 1	1·18	100 45	1·67	42 37	1·00	82 4
5	1·73	252 1	1·50	148 10	1·66	258 20	1·38	158 4	0·72	261 8	0·67	188 7	1·22	46 25	0·48	78 12	1·70	51 26	1·22	95 32	1·72	44 32	1·11	86 12
6	1·70	248 30	1·49	146 46	1·62	258 11	1·38	158 36	0·59	258 28	0·67	193 26	1·33	53 42	0·65	97 19	1·75	54 32	1·26	102 59	1·75	47 7	1·20	91 46
7	1·68	247 42	1·45	147 36	1·56	256 51	1·38	157 54	0·49	250 14	0·70	196 30	1·42	60 7	0·76	109 42	1·79	58 45	1·34	114 28	1·77	51 29	1·25	100 21
8	1·69	249 45	1·48	146 32	1·54	258 39	1·34	160 7	0·46	241 33	0·67	197 3	1·47	63 46	0·84	120 23	1·79	61 6	1·36	120 16	1·78	56 27	1·33	109 58
9	1·73	250 7	1·52	145 53	1·58	258 11	1·27	161 52	0·66	247 18	0·63	189 53	1·35	61 53	0·79	126 56	1·78	64 47	1·32	127 31	1·76	57 54	1·35	116 26
10	1·73	249 10	1·55	143 2	1·64	258 41	1·31	157 59	0·92	252 46	0·55	199 14	0·88	46 28	0·44	162 45	1·55	62 33	1·05	134 51	1·56	52 40	1·10	122 4
11	1·84	251 1	1·51	144 27	1·74	260 13	1·30	159 47	1·23	263 21	0·65	205 15	0·83	323 28	0·70	221 35	1·06	48 50	0·73	152 32	1·16	33 49	0·60	151 6
12	1·85	252 4	1·51	146 17	1·83	261 24	1·46	161 6	1·53	269 53	0·84	193 23	1·41	303 43	1·13	238 51	0·82	339 3	0·81	208 3	1·04	337 9	0·71	236 10
13	1·84	252 11	1·49	146 22	1·81	262 9	1·45	164 7	1·63	271 47	1·04	192 55	1·65	301 23	1·34	239 31	1·27	307 27	1·12	223 7	1·43	312 33	1·13	243 8
14	1·86	253 48	1·56	148 54	1·82	262 13	1·46	162 34	1·67	275 27	1·15	198 45	1·78	303 3	1·46	250 4	1·50	305 8	1·23	234 27	1·68	307 2	1·37	247 15
15	1·86	253 28	1·54	148 9	1·80	263 24	1·41	164 36	1·68	278 51	1·12	204 12	1·81	305 31	1·56	256 13	1·70	305 19	1·40	248 56	1·80	307 8	1·51	252 59
16	1·87	254 0	1·57	149 18	1·79	263 46	1·40	164 55	1·68	281 17	1·06	208 20	1·80	310 9	1·49	267 6	1·74	311 13	1·43	262 45	1·86	311 15	1·56	263 59
17	1·87	253 13	1·58	146 54	1·80	264 21	1·44	166 41	1·68	280 7	1·15	201 6	1·75	315 59	1·44	276 37	1·79	320 42	1·51	284 28	1·85	317 20	1·53	277 27
18	1·86	251 50	1·56	143 54	1·80	264 41	1·38	166 25	1·62	280 57	1·05	203 25	1·74	321 51	1·48	289 0	1·79	330 6	1·61	301 33	1·85	325 2	1·58	294 28
19	1·84	250 38	1·57	141 26	1·79	263 34	1·41	163 49	1·48	279 27	1·09	202 10	1·65	330 51	1·31	299 57	1·79	336 27	1·62	310 0	1·86	330 5	1·64	304 33
20	1·81	250 16	1·47	142 2	1·79	261 43	1·42	161 8	1·41	279 5	1·03	201 39	1·58	337 57	1·22	315 22	1·74	346 28	1·56	327 40	1·83	339 25	1·58	322 32
21	1·81	250 6	1·49	145 8	1·73	259 10	1·38	154 15	1·35	276 11	0·95	195 55	1·52	348 19	1·01	335 40	1·69	0 49	1·43	353 10	1·78	353 7	1·45	349 25
22	1·85	248 28	1·57	140 13	1·73	258 5	1·45	155 32	1·34	274 47	0·95	194 18	1·41	356 33	0·90	349 19	1·58	13 8	1·09	11 30	1·70	4 21	1·38	6 44
23	1·81	247 33	1·50	139 39	1·74	257 44	1·41	153 13	1·29	275 9	0·88	197 27	1·22	7 9	0·72	355 31	1·46	27 46	0·71	33 6	1·56	15 50	1·13	16 21
Resultant for 24 Hours	1·79	250 25	1·51	144 57	1·72	259 53	1·40	159 9	1·19	271 49	0·86	195 48	0·99	354 9	0·36	281 26	1·15	17 26	0·08	103 33	1·26	8 25	0·18	0 19

TABLE 144—*continued.*

Bombay Civil Hours.	November to Januarv.				February to April.				June to September.				Year.			
	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2	c_1	a_1	c_2	a_2
		° ′		° ′		°		°		°		°		° ′		° ′
0	1·50	23 27	0·80	26 7	1·39	329 45	0·94	309 59	1·48	251 43	1·13	151 2	0·82	314 36	0·06	96 20
1	1·48	30 47	0·69	40 17	1·33	336 0	0·92	320 6	1·46	252 35	1·13	153 27	0·74	318 39	0·12	112 53
2	1·50	36 29	0·67	59 13	1·29	341 47	0·88	328 49	1·43	251 6	1·12	151 32	0·66	323 21	0·20	109 42
3	1·57	37 56	0·80	66 31	1·25	352 13	0·90	344 11	1·40	251 9	1·08	152 59	0·62	332 9	0·29	97 16
4	1·61	39 33	0·90	72 1	1·21	2 56	0·87	357 42	1·35	251 2	1·07	154 37	0·59	341 56	0·39	94 39
5	1·65	40 29	1·00	74 13	1·19	13 44	0·81	9 51	1·26	250 52	1·03	157 37	0·55	353 4	0·45	97 54
6	1·68	44 53	1·04	84 23	1·21	23 9	0·74	20 49	1·21	248 51	1·01	159 10	0·51	5 59	0·52	105 9
7	1·70	49 25	1·08	96 33	1·19	32 50	0·67	35 25	1·16	246 24	0·98	159 12	0·46	20 45	0·59	113 36
8	1·72	53 23	1·15	105 50	1·07	35 33	0·40	34 36	1·16	246 27	0·98	159 18	0·41	25 19	0·61	126 31
9	1·68	55 55	1·10	114 4	0·80	24 14	0·06	296 8	1·27	247 33	0·96	158 13	0·30	6 17	0·62	141 19
10	1·48	51 36	0·82	124 28	0·83	326 49	0·53	237 56	1·42	249 4	0·97	152 6	0·45	309 11	0·62	160 4
11	1·05	28 42	0·40	172 32	1·42	301 58	1·05	237 56	1·58	253 28	1·01	154 35	0·92	290 38	0·69	189 46
12	1·05	331 5	0·77	239 41	1·76	295 48	1·34	234 4	1·68	256 31	1·13	156 53	1·36	285 23	0·89	205 45
13	1·47	310 29	1·15	244 8	1·85	296 40	1·50	256 17	1·71	257 48	1·18	159 34	1·57	285 6	1·03	212 30
14	1·66	307 18	1·33	248 36	1·86	298 29	1·53	239 54	1·73	259 25	1·23	162 2	1·65	286 26	1·09	217 29
15	1·77	308 32	1·44	256 51	1·86	301 26	1·53	245 43	1·72	260 47	1·20	163 35	1·67	288 33	1·07	224 8
16	1·80	313 31	1·48	268 39	1·86	304 47	1·50	251 31	1·71	261 40	1·19	164 4	1·66	291 38	1·00	231 24
17	1·82	320 20	1·51	284 14	1·85	306 25	1·49	256 3	1·71	261 27	1·23	163 12	1·62	294 16	0·90	237 47
18	1·84	327 50	1·62	298 57	1·80	309 43	1·43	265 2	1·68	260 52	1·17	161 39	1·56	297 42	0·79	250 8
19	1·85	332 25	1·66	306 28	1·75	312 20	1·38	273 32	1·61	258 23	1·17	158 45	1·47	300 6	0·68	259 9
20	1·82	341 12	1·60	322 49	1·66	315 35	1·27	281 17	1·57	257 22	1·13	159 6	1·35	303 29	0·52	272 37
21	1·76	353 3	1·46	345 0	1·56	319 57	1·11	290 58	1·54	255 12	1·13	156 33	1·21	307 45	0·29	293 12
22	1·68	3 28	1·28	1 4	1·45	324 8	1·00	299 34	1·16	253 34	1·16	154 22	1·07	310 34	0·13	323 34
23	1·56	13 43	1·03	11 19	1·43	325 53	0·95	301 50	1·50	252 53	1·10	152 21	0·94	312 30	0·05	351 34
Resultant for 24 Hours	1·26	6 10	0·27	339 47	1·26	325 47	0·72	280 15	1·49	254 33	1·10	157 25	0·92	305 29	0·32	200 25

211*a*. The figures 601 to 604 were constructed from the mean north and east components of the wind, for each hour of the day, shown in Table 144*a*.

TABLE 144*a*.

Period - -	November to January.		February to April.		June to September.		Year.	
Component - -	North.	East.	North.	East.	North.	East.	North.	East.
Hours.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
0 to 1	+ 4·6	+2·1	+ 5·3	− 3·1	−5·1	−11·8	+1·0	− 4·6
1 to 2	+ 4·4	+3·0	+ 5·3	− 2·3	−4·7	−12·0	+1·0	− 4·1
2 to 3	+ 4·5	+3·7	+ 5·2	− 1·7	−4·8	−11·8	+1·0	− 3·7
3 to 4	+ 5·1	+4·4	+ 5·0	− 0·7	−4·8	−11·7	+1·1	− 3·1
4 to 5	+ 5·4	+5·0	+ 4·8	+ 0·3	−4·5	−11·4	+1·2	− 2·6
5 to 6	+ 5·7	+5·5	+ 4·4	+ 1·3	−4·4	−10·9	+1·3	− 2·0
6 to 7	+ 5·4	+6·1	+ 3·9	+ 2·2	−4·4	−10·2	+1·0	− 1·2
7 to 8	+ 5·0	+6·8	+ 3·7	+ 2·8	−4·7	−10·1	+0·7	− 0·8
8 to 9	+ 4·8	+7·0	+ 3·6	+ 2·3	−4·4	−10·1	+0·7	− 0·9
9 to 10	+ 4·6	+6·4	+ 3·7	+ 0·8	−4·6	−11·0	+0·7	− 2·0
10 to 11	+ 3·8	+4·2	+ 3·8	− 3·1	−4·8	−12·2	+0·4	− 4·4
11 to 12	+ 4·0	+0·9	+ 4·8	− 7·3	−4·4	−13·4	+0·9	− 7·1
12 to 13	+ 4·8	−3·1	+ 5·8	−10·8	−4·2	−14·4	+1·7	− 9·8
13 to 14	+ 5·8	−6·2	+ 7·1	−12·6	−4·0	−15·1	+2·5	−11·5
14 to 15	+ 7·0	−8·2	+ 8·3	−13·6	−3·7	−15·6	+3·4	−12·5
15 to 16	+ 8·2	−9·0	+ 9·3	−13·7	−3·3	−15·6	+4·1	−12·7
16 to 17	+ 9·5	−8·7	+10·1	−13·0	−3·1	−15·2	+4·8	−12·3
17 to 18	+10·5	−7·5	+ 9·9	−11·5	−3·3	−14·8	+4·9	−11·4
18 to 19	+11·3	−6·1	+ 9·6	− 9·6	−3·3	−13·7	+5·0	− 9·9
19 to 20	+11·1	−5·2	+ 8·6	− 7·6	−3·9	−12·8	+4·4	− 8·5
20 to 21	+ 9·5	−3·1	+ 7·3	− 6·0	−4·1	−12·2	+3·4	− 7·2
21 to 22	+ 7·6	−0·9	+ 6·0	− 4·5	−4·4	−11·9	+2·4	− 6·0
22 to 23	+ 6·2	+0·3	+ 5·4	− 3·8	−4·6	−11·8	+1·8	− 5·4
23 to 0	+ 5·2	+1·4	+ 5·2	− 3·4	−4·7	−11·6	+1·3	− 4·8
Means for seven years	+ 6·4	0·0	+ 6·1	−4·9	−4·3	−12·6	+2·1	− 6·2

PART III.

TEMPERATURE OF THE PRESIDENCY.

212. The original records of temperature that we possess, besides those for Colába and the four military stations, are for so small a number of stations, and generally for such short periods, that in order to present anything like a complete representation of this element, we are under the necessity of supplementing them from existing authoritative publications. In so doing, we have, however, confined ourselves to the printed sheets of observations of the Goa Observatory, to the Report of Mr. James Glaisher "On the Meteorology of India," and to the Messieurs De Schlagintweit's "India and High Asia, Vol. IV., Meteorology," for the latter two of which works, the basis of observations is probably of the same kind, and collected in the same manner, but at an earlier date, as the manuscript records in our hands; these records consist of registers kept at the several civil and military hospitals under the direction of the medical officers in charge. The temperatures adopted generally by the Messieurs Schlagintweit are the means of the two observations taken at 6 a.m. (or sunrise) and 4 p.m. Mr. Glaisher adopts the mean of the maximum and minimum temperatures of the day. For ourselves, after a careful examination of the diurnal variations of temperature at Colába and the four military stations, we came to the conclusion that no practical advantage was to be gained by departing from the simple mean of the maximum and minimum temperatures, but that this mean is generally sufficiently near to that adopted by the Messieurs Schlagintweit, and to the mean of 24 hourly observations, to render the combination of results practically unobjectionable in a first endeavour to depict the general facts.

213. The numbers made use of in the present compilation are the monthly and annaul mean temperatures of the several stations; and the following statement has been drawn up to show the sources from which the data have been obtained, the length of the period of observation, and the hours of observation in each case. When values obtained from different sources have been combined, it has been with weights proportional to the periods of observation which yielded them. In the statement the following abbreviations are used:—

M refers to manuscript records in our hands, and implies that the result is derived from hourly observations, or has been corrected—by means of a limited number of hourly observations—to the mean of the 24 hours.

M± refers to manuscript records in our hands, and implies that the result is derived from observations of maximum and minimum daily temperature, being the mean of the monthly averages.

M s/4 refers to the manuscript records in our hands, and implies that the result is the mean of observations taken at 6 a.m. (or sunrise) and 4 p.m.

G refers to Glaisher's Report, and implies that the result is the mean of the monthly averages of maximum and minimum temperature.

S refers to Schlagintweit's "India and High Asia, Vol. IV.," and implies that the result is the mean of observations taken at 6 a.m. (or sunrise) and 4 p.m.

The observations being thus divided into classes, the figures prefixed to the symbolical letters represent the numbers of years of observations of the respective classes; and for stations which belong to none of the classes described, the figures only are entered in the table.

TABLE 145.

LIST of TEMPERATURE STATIONS, showing the SOURCES from which the DATA have been obtained and the PERIODS of OBSERVATION.

Consecutive No.	River Basin or other Tract.	Station.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Remarks.
1	INDUS, right slope.	Kurrachee	12 M	12 M	12 M	12 M	12 M	12 M	12 M	12 M	12 M	11 M	11 M	11 M	
2		Sehwan									1 M s/4	1 M s/4	1 M s/4		
3		Mehur						1 M s/4	1 M s/4	1 M s/4	1 M s/4	1 M s/4	1 M s/4		
4		Shikárpur					1 M s/4	2 M s/4	1 M s/4	2 M s/4	3 M s/4	3 M s/4	2 M s/4		
5		Jacobabad	12 G	12 G	12 G	12 G	12 G	1 M s/4 12 G	1 M s/4 12 G	1 M s/4 12 G	1 M s/4 13 G	1 M s/4 12 G	1 M s/4 12 G	12 G	
6	INDUS, left slope.	Mitti						2 M±	1 M±	2 M±	3 M±	3 M±	1 M±		
7		Umarkot								1 M s/4	1 M s/4	1 M s/4			
8		Tando Muhammad Khan									1 M±	1 M±			
9		Hyderabad	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	
10		Tando Alahyar					1 M s/4	1 M s/4	1 M s/4	1 M s/4	1 M s/4	1 M s/4	1 M s/4		
11	KUTCH	Bhuj	2 S	2 S	2 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	
12	KATTIWAR.	Rajkot	2 M s/4 4 S	2 M s/4 4 S	2 M s/4 4 S	2 M s/4 4 S	1 M s/4 4 S	1 M s/4 3 S	1 M s/4 3 S	1 M s/4 3 S	2 M s/4 3 S	2 M s/4 3 S	2 M s/4 3 S	1 M s/4 3 S	
13		Gogo	1	2	2	2	2	2	3	3	3	3	2	2	Source:—Manuscript. Hours:—6, noon, and 21.
14	WESTERN BUNNASS, left slope.	Deesa	15 M	16 M	16 M	16 M	16 M	17 M	16 M	16 M	16 M	15 M	15 M	16 M	
15	SÁBARMATI left slope.	Ahmedabad	2 S	2 S	2 S	2 S	5 M s/4 2 S	5 M s/4 2 S	4 M s/4 2 S	5 M s/4 2 S	5 M s/4 2 S	5 M s/4 2 S	5 M s/4 2 S	2 S	
16	MÁHI, left slope.	Baroda	2 M s/4	2 M s/4	2 M s/4	2 M s/4	2 M s/4	2 M s/4	2 M s/4	2 M s/4	2 M s/4	3 M s/4	2 M s/4	2 M s/4	
17	TAPTI, left slope.	Málegaon	2 M±	3 M±	3 M±	3 M±	3 M±	1 M±	2 M±	3 M±	1 M±	1 M±	3 M±	3 M±	
18		Dhulia	6 G	6 G	6 G	6 G	6 G	6 G	6 G	6 G	1 M s/4 6 G	1 M s/4 6 G	6 G	6 G	
19	KONKAN.	Bulsar	1 M±	1 M±	1 M±	1 M±	1 M±	1 M±	1 M±		1 M±	1 M±		1 M±	
20		Bombay	7 M	7 M	7 M	7 M	7 M	7 M	7 M	7 M	7 M	7 M	7 M	7 M	
21		Dápoli	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	
22		Ratnágiri	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	
23		Vingorla	4 G	4 G	4 G	4 G	4 G	4 G	4 G	4 G	4 G	4 G	4 G	4 G	
24		Goa	10	10	10	11	11	10	9	9	9	9	9	10	*
25		Matheran	6 M s/4	6 M s/4	6 M s/4	5 M s/4	6 M s/4	5 M s/4	6 M s/4	6 M s/4	6 M s/4	6 M s/4	6 M s/4	6 M s/4	
26	GUNGAWALI near source.	Dharwar	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	2 G	
27	ARAVULLI, Range.	Mount Abu	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	5 G 5 M s/4	
28		Erinpura	1	1	2	3	3	3	3	3	3	2	1	—	Source:—Schlagintweit. Hours:—Sunrise and noon.
29		Beavr		1	1	1	1	1	1	1	1		1		Source:—Schlagintweit. Mean of maximum and minimum.
30		Ajmir	2 S	2 S	2 S	2 S	2 S	3 S	2 S	3 S	3 S	2 S	3 S	2 S	

* Monthly mean values abstracted from printed sheets of observations of the Goa Observatory, 1860-71. Hours:—Minimum, 9, maximum, and 21

TABLE 145—*continued.*

LIST of TEMPERATURE STATIONS, showing the SOURCES from which the DATA have been obtained and the PERIODS of OBSERVATION—*continued.*

Consecutive No.	River Basin or other Tract.	Station.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Remarks.
31		Nasirabad	2 M s/4	1 M s/4	1 M s/4	1 M s/4	4 M s/4	4 M s/4	3 M s/4	4 M s/4	5 M s/4	5 M s/4	5 M s/4	1 M s/4	
32	MALWA Plateau.	Nimach	3 S 1 G 1 M±	3 S 1 G 1 M±	3 S 1 G 1 M±	3 S 1 G 1 M±	4 S 1 G 1 M±	4 S 1 G 1 M s/4	4 S 1 G 1 M s/4	4 S 1 G 1 M s/4	3 S 1 G 1 M s/4	3 S 1 G 1 M s/4	3 S 1 G 1 M s/4	2 S 1 G	
33		Mehidpur							1 M s/4	1 M s/4	2 M s/4	2 M s/4			
34		Mhow	2 G 4 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 4 M s/4	2 G 4 M s/4	2 G 4 M s/4	2 G 2 M s/4	
35	GODÁVARI, *left slope.*	Jálna	2 S	2 S	2 S	2 S	2 S	2 S	2 S	2 S	2 S	2 S	2 S	2 S	
36	BHIMA, left slope.	Akalkot									1 M±	1 M±	1 M±		
37		Sholapur	11 G 1 M s/4	11 G 2 M s/4	11 G 2 M s/4	11 G 2 M s/4	11 G 3 M s/4	11 G 3 M s/4	11 G 2 M s/4	11 G 3 M s/4	11 G 4 M s/4	11 G 3 M s/4	11 G 3 M s/4	11 G 2 M s/4	
38		Ahmednagar	6 G	6 G	6 G	6 G	1 M± 6 G	1 M± 6 G	1 M± 6 G	1 M± 6 G	2 M± 6 G	2 M± 6 G	1 M± 6 G	6 G	
39		Sirur	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	1 M s/4 5 G	1 M s/4 5 G	1 M s/4 5 G	5 G	
40	BHIMA, right slope.	Bijápur	1	1	1	1	1	1	1	1	1	1	1	1	Source :— Schlagintweit. Hours : — Not stated.
41		Phaltan	1	1	1	1	1	1	1	1	1	1	1	1	Source :— Schlagintweit. Hours : — Not stated.
42		Purandhar	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 2 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	2 G 3 M s/4	
43		Poona	17 M	17 M	17 M	17 M	17 M	16 M	17 M	17 M	17 M	17 M	17 M	17 M	
44		Kirkee	2	2	2	2	2	2	2	2	2	2	2	2	Source :— Schlagintweit. Hours : — Not stated.
45	KRISHNA, right slope.	Kaladgi	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	5 G	
46		Belgaum	17 M	17 M	17 M	17 M	17 M	17 M	16 M	17 M	17 M	17 M	17 M	17 M	
47		Kolhápur	10 G	10 G	10 G	10 G	10 G	10 G	10 G	10 G	10 G	10 G	10 G	10 G	
48		Satara	G	G	G	G	G	G	G	G	G	G	G	G	Period : — Not stated.
49		Pánchgani	Period :—1854-62. Hours :—Sunrise, 10, 12, 16, sunset, and 20.												Source : — Schlagintweit. Place :—A tiled house.
50		Mahablesh-war.	1 G 9 M s/4	1 G 10 M s/4	1 G 10 M s/4	1 G 9 M s/4	1 G 9 M s/4	1 G 9 M s/4	1 G 7 M s/4	1 G 9 M s/4	1 G 9 M s/4	1 G 9 M s/4	1 G 9 M s/4	1 G 9 M s/4	
51		Mánderdew							1 M s/4	1 M s/4	1 M s/4	1 M s/4			
52	TUNGABHADRA, right slope.	Harihár	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	1 S	

214. The adopted monthly and annual mean temperatures of the several stations, and the ranges between the greatest and least monthly means, are shown in Table 146.

TABLE 146.

Consecutive No.	Station.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean.	Range between greatest and least Monthly Means.
1	Kurrachee	63·1	66·5	73·5	79·3	82·5	85·5	84·2	80·9	80·6	77·0	71·3	65·8	75·8	22·4
2	Sehwan									97·0	82·7	77·7			
3	Mehur						101·3	97·2	95·7	94·6	81·6	71·5			
4	Shikárpur					93·8	97·5	93·7	91·7	88·0	77·2	70·0			
5	Jacobabad	60·5	65·0	74·5	85·0	95·5	99·3	97·3	92·4	90·4	80·8	70·0	62·5	81·1	38·8
6	Mitti						92·7	88·8	88·0	86·6	86·5	80·2			
7	Umarkot								87·9	85·9	84·9				
8	Tando Muhammad Khan									88·5	84·8				
9	Hyderabad	64·5	70·0	80·5	86·0	91·0	92·0	89·5	87·5	85·0	82·5	72·5	65·5	80·5	27·5
10	Tando Aláhyar					95·7	96·8	92·2	89·6	87·5	87·7	82·6			
11	Bhuj	65·5	71·5	79·5	82·0	84·0	87·0	81·0	80·0	79·0	75·0	70·0	59·0	76·1	28·0
12	Rajkot	68·7	73·0	80·0	87·1	91·0	88·9	84·3	81·7	81·5	82·4	77·0	71·5	80·6	22·3
13	Gogo	67·9	70·6	79·1	84·6	87·7	86·6	82·7	81·3	82·5	82·6	78·2	73·4	79·8	19·8
14	Deesa	65·5	70·9	78·1	88·6	92·5	91·0	85·6	81·6	81·5	79·6	73·6	68·6	79·8	27·0
15	Ahmedabad	71·0	80·0	83·0	93·0	94·3	89·6	86·3	83·1	83·7	84·3	80·3	69·0	83·1	25·3
16	Baroda	70·3	72·1	81·7	88·6	90·6	88·8	83·5	80·4	82·8	81·2	80·9	74·6	80·5	20·3
17	Málegaon	72·4	76·2	82·1	89·7	90·1	86·5	81·4	81·5	79·5	77·0	77·0	73·2	80·5	17·7
18	Dhulia	71·0	75·5	82·0	88·5	92·0	87·5	82·0	80·5	80·0	79·6	74·0	71·0	80·3	21·0
19	Bulsar	71·0	73·1	76·8	84·5	86·1	85·2	82·2		82·8	82·0		73·1		
20	Bombay	73·6	74·4	77·9	81·4	84·2	83·3	80·4	79·6	79·7	80·5	78·6	76·4	79·2	10·6
21	Dápoli	74·5	75·5	80·0	83·5	83·5	80·5	79·0	76·5	77·5	79·0	79·0	74·0	78·5	9·5
22	Ratnágiri	78·0	79·0	82·0	84·0	85·0	83·0	79·5	80·0	81·0	80·5	79·0	78·5	80·8	7·0
23	Vingorla	78·0	79·0	81·5	83·5	84·0	81·0	79·5	79·0	79·0	80·5	79·0	79·0	80·2	6·0
24	Goa	81·1	81·6	82·8	84·9	85·6	82·1	80·1	79·6	80·3	82·2	82·6	82·0	82·1	6·0
25	Matheran	69·0	73·0	73·4	78·0	77·1	73·5	71·8	70·9	71·9	73·0	73·3	71·3	73·0	8·9
26	Dharwar	72·0	80·0	83·0	82·0	84·0	79·0	76·5	73·5	73·5	76·5	77·0	72·0	77·4	12·0
27	Mount Abu	56·7	61·5	68·8	75·5	79·3	77·6	72·0	69·2	69·1	69·2	65·0	58·7	68·5	22·6
28	Erinpura	48·5	59·0	70·5	84·1	89·4	90·3	85·0	82·2	81·5	77·4	67·2			
29	Beavr		64·7	75·1	88·2	94·5	91·7	85·8	82·6	82·6		68·9			
30	Ajmir	61·7	69·3	78·3	87·4	94·3	92·5	85·6	82·7	83·5	82·2	73·0	65·1	79·6	32·6
31	Násirabad	58·9	70·0	72·1	85·3	93·8	91·7	85·4	83·8	83·8	80·8	73·8	65·4	78·7	34·9
32	Nimach	61·3	68·3	75·5	84·6	88·7	84·9	78·5	77·2	77·9	77·1	71·7	65·3	75·9	27·4
33	Mehidpur							78·2	77·0	78·3	77·5				
34	Mhow	66·3	71·2	77·7	85·1	86·9	79·7	77·1	75·7	76·2	77·0	71·3	67·9	76 0	20·6
35	Jálna	74·3	75·7	83·2	87·0	90·0	83·0	77 2	79·0	77·0	79·4	77·0	72·5	79·6	17·5
36	Akalkot									80·8	81·9	79·9			
37	Sholapur	74·5	78·2	84·3	89·1	88·6	83·2	80·4	80·5	80·1	79·6	76·7	72·4	80·6	16·7
38	Ahmednágar	71·0	74·5	81·5	86·5	87·4	81·0	77·9	76·6	75·9	76·8	72·2	69·5	77·6	17·9
39	Sirur	72·0	72·5	80·0	85·5	83·5	82·5	79·5	78·0	75·5	81·3	76·0	74·5	78·4	13·5
40	Bijapur	78·5	75·3	84·8	88·4	88·5	85·0	81·2	78·7	78·2	76·6	76·7	79·2	80·9	13·2
41	Phaltan	74·8	76·9	83·9	83·9	86·1	81·2	80·2	79·3	78·9	80·0	73·5	72·9	79·3	13·2
42	Purandhar	67·1	71·7	75·1	77·0	72·8	70·3	67·3	65·9	67·2	69·6	67·7	64·4	69·7	12·6
43	Poona	71·4	75·6	80·2	84·6	83·7	78·9	75·5	74·4	75·0	76·6	74·6	71·7	76·8	13·2
44	Kirkee	71·0	75·0	81·0	81·5	82·5	78·5	77·0	75·0	75·0	80·0	77·0	71·0	77·0	11·5
45	Kaladgi	74·5	79·0	87·5	89·0	87·5	84·0	82·0	83·0	82·0	79·5	75·5	72·5	81·3	16·5
46	Belgaum	70·7	74·1	77·5	80·0	78·4	74·0	71·3	70·3	71·4	73·4	72·1	70·4	73·6	9·7
47	Kolhápur	72·0	75·5	81·0	82·0	83·0	78·5	75·5	75·0	76·0	77·5	75·0	72·0	76·9	11·0
48	Satara	73·0	74·0	80·0	83·5	82·5	76·0	73·5	73·0	74·0	74·0	71·5	71·0	75·5	12·5
49	Pánchgani	66·0	71·0	75·0	77·0	76·0	69·0	66·0	65·0	65·0	67·0	67·0	65·0	69·1	12·0
50	Mahableshwar	64·3	68·2	72·4	75·6	73·1	66·3	64·2	63·9	63·9	66·3	65·1	64·2	67·3	11·4
51	Manderdew							65·7	64·4	64·8	67·9				
52	Harihár	74·0	78·9	86·1	87·7	86·7	81·2	75·8	78·7	79 0	80·7	79·3	75·0	80·3	13·7

The numbers in this table have been entered in red ink by the side of black dots placed over the positions of the respective stations in the maps (Plates LV. to LXVIII.), of which here is one for each month, one for the annual mean temperatures, and one for ranges of temperature between the greatest and least monthly means.

Violet lines have been drawn on the maps with a free hand, so as to enclose groups of stations of nearly equal temperature, and the average temperatures of such groups of stations are marked in violet figures, but the dots and numbers representing the temperatures of the hill stations, Mount Abu, Mahableshwar, Panchgani, Manderdew, Purandhar, and Matheran, are also enclosed singly, to imply that, whether or not lying within any of the grouping lines, such numbers are to be considered apart from the averages of the groups, into the calculation of which they have not entered. Also the dots and numbers of Belgaum for April, June, July, September, and October, of Surat for February, of Dápoli for August, and of Bijapur for October, have been similarly enclosed singly, because the numbers differ to an unusual extent from the averages of the respective groups with which they are enclosed, and these numbers are excluded in calculating the averages.

NOTES on the DISTRIBUTION and ANNUAL VARIATION of TEMPERATURE as shown by the Maps, Plates LV. to LXVIII.

215. It will sometimes be convenient to regard the low lands extending along the Indus valley, through Guzerat and the Konkan along the foot of the Western Ghauts, apart from the high lands of the Deccan and Malwa: we shall distinguish the former portion of the Presidency, including the lower parts of the valleys of the Nerbudda and Tapti rivers, as the low region, and the latter as the high region. Stations of great elevation as compared with the surrounding country, such as Mount Abu and Mahableshwar, must be understood to be for the present put out of account.

216. January.—The sun being in this month far to southward of the equator, there is everywhere, except in the Deccan, a gradation of temperature increasing from north to south. In the low region the increase is at a nearly uniform rate from 60° at Jacobabad to 81° at Goa. Proceeding inland from Kattywar to the lower courses of the Mahi and neighbouring rivers, there is a rise of 2° in the temperature. The portion of the Deccan which our observations embrace, extending to the meridian of 76° and to the parallel of 11°, is divided into two strips, whose length direction is meridional: the eastern strip has an average temperature of about 74°, and the one nearer to the Ghauts of about 72°; here, as in the case already mentioned, of Kattywar and the lower Mahi valley, showing an increase with progress inland. The average temperature of the Konkan is about 3° higher than that of the Deccan. The Malwa plateau has, at Mhow in the south, a temperature of 66°, diminishing to 60° in the north (the Ajmir district). This is the coldest month of the year in all parts of the Presidency, except the following, viz.: the whole of the Deccan except a small surrounding of that part of the Ghauts where the ridge is highest, Bhuj, Ahmedabad, and the Vingorla-Goa district of the Konkan. In the latter district there is a minimum of temperature in January, but there is also a lower minimum in August; in all the other excepted districts the minimum of the year occurs in December.

217. February.—The gradual increase of temperature from north to south is general, but there is little difference between large portions of the Deccan. In the low region the

temperature varies from 65° at Jacobabad to 81° at Goa, and in the high region from 68° in the Ajmir district to 71° at Mhow, and from 75° over the greater part of the Deccan (Jalna to Belgaum) to 79° in the south and south-eastern portion (Sholapur-Harihár). Ahmedabad and Surat have already abnormally high temperatures, and the upper left basin of the Tapti river, being well inland, and of less elevation than the districts to north and south of it, is 3° warmer than the coast in the same latitude, and 1° warmer than the greater (northern and western) part of the Deccan. From January to February increase of temperature is considerable everywhere except in the southern half of the Konkan, where also it is noticeable; but whilst Hyderabad on the Indus and Bhuj have increased 6°, Kurrachee on the coast has only increased 3°.

218. March.—Along the coast the temperature increases from 73° at Kurrachee to 83° at Goa. Inland there is a corresponding but more rapid increase from 74° at Jacobabad to 83° about the lower courses of the Sábarmati, Mahi, Nerbudda, and Tapti rivers, the latter having become a district of maximum temperature. In the high region the Ajmir district has still a temperature 3° less than Mhow, where it is 78°; and of the eastern portion of the Deccan the middle part has a temperature of 84°, and the southern of 87°, still increasing southward: the western half of the Deccan is a district of minimum temperature (81°), except as regards the direction to seaward. Against an increase, since February, of about 3° on the coast, we have an increase of 8° in Sind and Guzerat, and an average increase of 6° or 7° in the high region.

219. April.—The temperature increases along the coast from 79° at Kurrachee to 85° at Goa, and inland from 85° at Jacobabad to 89° in the lower valleys of the Nerbudda and Tapti rivers. The region of maximum temperature has extended, since March, to Deesa northward, Rajkot eastward, and up the Tapti valley. Ahmedabad in the interior of the region gives a temperature of 93°. The northern edge of the Malwa plateau (the Ajmir district) has now acquired a higher temperature (88°) than the southern edge (85°), but the southern part of the eastern portion of the Deccan is still hotter (88°) than the northern part (86°). The western portion of the Deccan with a temperature of 83° is more decidedly a minimum district than in March. The increase of temperature since March is about 8° in Sind and Guzerat, 10° in Malwa, 4° on the coast, and 2° in the Deccan.

220. May.—An increase is observed along the coast from 83° at Kurrachee to 85° at Goa; inland there is no longer an increase, but a decrease from 94° in Upper Sind to 91° in the Tapti valley: there is also a decrease in Malwa from 94° in the Ajmir district to 87° at Mhow. In the Deccan, the middle of the western portion included between the sources and upper courses of the Bhima and Krishna rivers is still a minimum district (83°); further down the rivers, near our eastern boundary, the temperature is 88°; and the increase from the minimum district towards Jalna is gradual. The highest temperatures extend now along the whole northern boundary of the Presidency from Upper Sind, through Guzerat, to Malwa. The increase of temperature since April is 10° at Jacobabad, 3° in Lower Sind and Guzerat, 5° in Malwa, none in the Deccan, and 2° on the coast.

221. June.—Except in Sind, where, on the coast and about Jacobabad, a rise of 3° and 4° has occurred, the temperature of the whole Presidency has fallen since May: in Guzerat

the fall is 3° in extent, in the Deccan and the left basin of the Upper Tapti river it is 4°, and in the Konkan, which has now a temperature of 82°, the fall is 2°; in Malwa it is 2° in the Ajmir district and 7° at Mhow. The temperature decreases from a maximum of 98° in the Jacobabad district to 90° in Guzerat north, 88° in Guzerat south, and 87° in the Upper Tapti valley. There is another maximum of 92° on the northern edge of the Malwa plateau, and in the Deccan the order of increase (from 78° to 84°) is as usual from the edge of the Ghauts inland, the minimum of the Presidency (78°) occupying the former position. The coast of Sind has now a temperature of 86°, being 4° warmer, instead of cooler as hitherto, than the coast of the Konkan. Mehar has a temperature of 101°, or 3° in excess of the average of the group of stations to the north of it .

222. July.—From June to July the temperature decreases over the whole of the Presidency. The amounts of change are, in Sind an average of 3°, in Guzerat 4°, in the Upper Tapti valley and north-eastern part of the Deccan 5°, in the south-eastern part of the Deccan 3°, in the western part of the Deccan and in the Konkan 2°, and in Malwa, north and south, 6° and 3° respectively. The decrease, it will be observed, is greatest in the north of the Deccan, and in the north of Malwa. The middle of our region of least temperature (76°) occupies its usual position opposite the highest part of the Ghauts (the Mahableshwar district), but from the northern and southern extremities of its usual enclosure, arms stretch away far to north-eastward and south-eastward, showing a tendency to enwrap the region of higher temperature (81°) to eastward. Inland there is a gradual decrease from 96° in Upper Sind (through Guzerat) to 82° in the Upper Tapti valley, and in Malwa from 86° on the northern edge to 77° at Mhow. The coast of the Konkan has a temperature of 80°, that of Sind at Kurrachee 84°. North of the Tapti river the temperature increases up to the northern boundaries of the Presidency both in Sind, Guzerat, and Malwa.

223. August.—The coast throughout is at a uniform temperature of 80°. Inland there is a gradual decrease from 93° in Upper Sind to an average of 82° in Guzerat, and 81° in the Upper Tapti valley; and in Malwa from 83° in the north to 76° at Mhow. The eastern and western portions of the Deccan have temperatures of 79° and 75° respectively, showing a general reduction since July of about 1°. Reductions are also shown of 3° in the north of Malwa and 1° in the south; of 4° in the north of Guzerat and 1° in the south, including the Tapti valley; and of 2° or 3° in Sind generally. The maximum has begun to recede southward, Mehar having now a temperature of 96°.

224. September.—The coast throughout has still a nearly uniform temperature of about 80°. The maximum temperature (96°) now appears further southward in the Mehar-Sehwan district, whilst the temperature of the Jacobabad district has fallen to 89°, or 7° below the maximum. South-eastward from the maximum district there is a gradual decrease to 80° in the Upper Tapti valley. North of Ahmedabad the temperature is now lower by about 1° than in Guzerat proper, a condition the reverse of which has held till now since April, but which continues henceforth for the remainder of the year. The north of Malwa (83°) is still, however, 5° warmer than the south. In the Deccan no noteworthy change has taken place since August; but in Upper Sind there has been a fall of 3°, and in Lower Sind and the Upper Tapti valley of 1°, whilst in Guzerat and South Malwa there has been a rise of 1°.

225. October.—The region of maximum temperature (85°) has come further southward, and now occupies Lower Sind; the decrease northward to Upper Sind is 6°, and south-eastward to the Upper Tapti valley 7°. The north of Malwa (81°) is still 4° warmer than the south. The western and eastern portions of the Deccan have temperatures of 77° and 80° respectively, the former being, as usual, the region of minimum temperature. The coast of the Konkan has still a temperature of 80°, but that of Sind, as shown by the temperature of Kurrachee, is now 77°, having fallen 3° since September. The fall of temperature since September is in Upper Sind as much as 10° in the north, and 14° further south; in Lower Sind, Guzerat north, Malwa, and the Upper Tapti valley it is only about 1°, and it is still less in Guzerat proper. The temperature of the minimum region of the Deccan has increased 2°, that of the eastern portion about 1°.

226. November.—The coast of the Konkan has a nearly uniform temperature of 79°; beyond, to Kurrachee, it diminishes to 71°. The region of maximum temperature (81°) is now a contracted one about the lower courses of the Sábarmati and Mahi rivers; and the Deccan minimum region (74°) holds its usual position at the western side of the plateau. The eastern side of the Deccan has a temperature of 77°; that of Malwa, now nearly the same north and south, is 71°, of Lower Sind 78°, and of Upper Sind 70°. The decrease since October, in Upper and Lower Sind respectively, is 8° and 7°; in Guzerat north 6°, in Guzerat proper 3°, in the north of Malwa 11°, and in the south 6°, on the Deccan generally 3°, and in the Konkan 1°.

227. December.—The temperature of the low region, inland and coast, increases gradually from 62° at Jacobabad, and 66° at Kurrachee, to 79° in the southern Konkan. North and South Malwa have temperatures of 65° and 68° respectively. Except the minimum region (71°), which has been contracting since September, and which now extends only from Poona to Satara, the Deccan generally has a temperature of 73°. The decrease since November is in Sind about 8°, in Guzerat 6°, in Malwa, north and south, 7° and 3°, in the Deccan and northern half of the Konkan 4°, and in the Konkan from Ratnágiri southward there is no change. The further decrease from this month to January is about 2° in Sind, 4° in North Malwa, and 2° at Mhow, 4° in Guzerat with exception of Ahmedabad, which has gained 2°, 1° in the Konkan, and 2° on the coast at Kurrachee; there is, on the contrary, a rise, in the same period, of 2° in the eastern side of the Deccan and a fraction of a degree in the western side.

228. Year.—The mean temperatures of the year show a remarkable uniformity over widely separated and differently conditioned portions of the country: thus, the average temperature of the whole of the Konkan, together with Guzerat and the Upper Tapti valley, is 80°, of the two inland stations in Sind 81°, of the southern group of stations on the eastern side of the Deccan 81°, and of the northern group 79°. The coast of Sind and South Malwa have each a temperature of 76°, North Malwa of 79°, and the western or Ghaut side of the Deccan of about 77°. The length direction of the enclosures of the two groups on the eastern side of the Deccan, it will be observed, runs generally athwart the river courses, whilst the stations of the district of minimum temperature form a strip, running along the whole length of the edge of the Ghauts, and therefore containing the sources of the rivers; hence, as the beds of the rivers are not generally deep relatively to their watersheds, the minimum district is one of relatively greater elevation than the district of higher temperature

to the east of it. For much the greater part of the year the large cities of Ahmedabad and Surat, as also Goa, have temperatures in excess of the average of their several localities; this may possibly arise from an obstructed circulation unaccompanied by any diminution of radiant heat received from the sun; or the conditions of life in densely populated places may alone suffice to heat sensibly the great body of superficial air which envelops them. The simple alternative explanation is that the thermometers of those stations are incorrect, but, in view of the general accordance of the temperature results at large, we prefer to hold that explanation in abeyance till decisive evidence is available: any probable difference of exposure we regard as incompetent to produce differences of temperature of the magnitude of those referred to, reaching 4° in some instances in the average temperature of a month. This last remark must not be held to apply to the *diurnal* range of temperature; for it is because differences of exposure largely affect the observed values of this element that we have refrained from using the large body of observations at our disposal to determine it, believing that the results would be more delusive than informing.

229. General view.—In the low region inland the variation of temperature with latitude is, from December to January, that which is general in the northern hemisphere when the sun's declination is south, viz., a decrease with increasing north latitude. In March, however, a circuit of maximum temperature has already begun to form in Guzerat; this circuit extends northward, its centre travelling northward at the same time, till June, when it has reached our northern limits in Upper Sind; there it remains till July, and then extends and travels southward, reaching Lower Sind in October, and, in a contracted form, Guzerat in November; here it first appeared on the sun's approach northward, and here it vanishes with the sun's progress southward. From June to November the coast of the Konkan has nearly the same temperature in one latitude as in another, but in the months December to April there is a considerable diminution, and in May a sensible diminution, with increase of latitude. The temperature of the coast of Sind exceeds that of the Konkan in June and July considerably, and in August and September sensibly, but in the remaining months of the year the coast of Sind is the cooler, the excess of the temperature of Goa above that of Kurrachee reaching in January as much as 18°. In the high region the Malwa plateau has a higher temperature in the north than in the south between March and November, and the reverse condition between November and March; whilst in the Deccan the eastern side shows a greater temperature in the south than in the north from February to April, but only the invariable increase from west to east in other months; and the western side exhibits no decided indications of variation with latitude at any season.

230. The presentation before the mind, in some manner similar to that which has been attempted, of pictures of the distribution of temperature with respect to space at different times is essential to a complete knowledge of the climate of a country; and it might be supposed that when the same phenomena were viewed under a different aspect, that is, by means of a picture of an average distribution of temperature, or of the distribution for some one time, together with representations of the variation of temperature with respect to time in different localities, the same degree of complication would attach to both modes of representation; this, it will be seen, is by no means the case, but that a comparatively simple variation of temperature with time, of different extent for different localities, gives rise to the varied distributions that have been described as characterising

the different months of the year. In the present case, for the single picture which is to be varied by the superposition of the variations of temperature with respect to time, we choose that which exhibits the mean temperatures of the year (Plate LXVII.), and for representation of the variations we divide the country into districts of like general geographical character, and approximating to equality of range of temperature from the coldest to the hottest month; for these districts we calculate the average temperature of the stations included in them respectively for each month, and take the excesses of the monthly means above the general means. These excesses (the mean annual variation of temperature) are the amounts by which the temperatures of the districts shown on the annual map must be increased to obtain the corresponding temperatures for the several months; and they are curved, in the manner which we have already frequently used for exhibiting a simple variation with time, in figures 709 to 720. The groupings of stations adopted are as follows:—

TABLE 147.

Group No.	Districts.	Stations.
1	Upper Sind.	Jacobabad.
2	Lower Sind.	Hyderabad.
3	Guzerat and Tapti Valley.	Deesa. Ahmedabad. Baroda. Dhulia.
4	On or near coast from Surat to Kurrachee.	Kurrachee. Bhuj. Rajkot. Gogo. Surat.
5	Konkan, South (1).	Bombay. Dápoli.
6	Konkan, South (2).	Ratnágiri. Vingorla. Goa.
7	Malwa Plateau, North.	Ajmir. Nasirabad.
8	Malwa Plateau, South.	Nimach. Mhow.
9	Deccan, East	Malegaon. Jálna. Ahmednagar. Sholapur. Bijápur. Kaladgi. Harihár.
10	Deccan, West.	Sirur. Kirkee. Poona. Phaltan. Satara. Kolhápur. Belgaum. Dharwar.
11	Hill stations in the Konkan and Deccan.	Matheran. Purandhar. Mahableshwar. Pánchgani.
12	Hill station in Rajputana.	Mount Abu.

231. The monthly excesses and the annual mean temperatures of the several groups are shown in Table 148.

TABLE 148.

Group.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual Mean Temperature.
1	−20·6	−16·1	−6·6	+3·9	+14·4	+18·2	+16·2	+11·3	+9·3	−0·3	−11·1	−18·6	81°1
2	−16·0	−10·5	0·0	+5·5	+10·5	+11·5	+ 9·0	+ 7·0	+4·5	+2·0	− 8·0	−15·0	80 5
3	−11·7	− 6·5	+0·1	+8·6	+11·2	+ 8·1	+ 3·2	+ 0·3	+0·9	+0·1	− 3·9	−10·3	81·1
4	−11·4	− 6·7	+0·2	+5·3	+ 8·0	+ 8·0	+ 4·2	+ 2·4	+2·4	+1·0	− 3·9	−10·0	79·0
5	− 4·8	− 3·9	+0·1	+3·6	+ 5·0	+ 3·1	+ 0·9	− 0·8	−0·2	+0·9	0·0	− 3·6	78·8
6	− 2·0	− 1·1	+1·1	+3·1	+ 3·9	+ 1·0	− 1·3	− 1·5	−0·9	+0·1	− 0·8	− 1·2	81·0
7	−18·1	− 8·9	−2·8	+7·5	+13·9	+13·0	+ 6·5	+ 3·7	+3·8	+2·1	− 5·9	−14·6	79·4
8	−12·1	− 6·2	+0·7	+8·9	+11·9	+ 6·4	+ 1·9	+ 0·5	+1·1	+1·1	− 4·4	− 9·3	75·9
9	− 5·9	− 3·3	+4·1	+8·1	+ 8·3	+ 3·3	− 0·7	− 0·4	−1·3	−1·6	− 3·8	− 6·6	80·1
10	− 4·8	− 1·5	+3·9	+6·0	+ 6·1	+ 1·7	− 0·8	− 2·1	−2·0	+0·5	− 2·3	− 5·0	76·9
11	− 3·2	+ 1·2	+4·2	+7·1	+ 4·9	0·0	− 2·5	− 3·4	−2·8	−0·8	− 1·5	− 3·6	69·8
12	−11·8	− 7·0	+0·3	+7·0	+10·8	+ 9·1	+ 3·5	+ 0·7	+0·6	+0·7	− 3·5	− 9·8	68·5
Mean of all the stations	69·9	73·8	79·7	84·4	85·9	82·8	79·3	77·9	77·9	78·0	74·6	70·6	77·9

232. A careful study of the curves (figures 709 to 721) conducts us to the same conclusions that have been stated in paragraphs 180 to 184 in the course of our discussion of similar curves for the five military stations only. The minimum temperature of the year occurs in the Vingorla-Goa group in August, the middle of the monsoon; in the eastern side of the Deccan in December; at the hill stations of group 11, and in the western side of the Deccan, near the beginning of the year; and everywhere else decidedly in January. It is followed by a rise which reaches a maximum later and later as we proceed northward, whether in the low region or high region. In the Vingorla-Goa group the maximum occurs in the first fortnight of May, and at Jacobabad about the middle of June, and, paying attention to the curvature of the curves about this period, it will be seen that the progression is gradual from group to group as we advance northward. In the Deccan generally the maximum is reached about the beginning of May, and in the North Malwa group not till the last fortnight of that month, whilst in South Malwa the maximum occurs at a time intermediate between the two last. At the hill stations the maximum occurs in April, and is 10°·7 above the minimum of December. For the reasons given in paragraphs 181–2, the times of occurrence of these maxima may be regarded as marking the effective arrival of the monsoon, and the gradual progression of the latter from south to north is clearly indicated by the feature in the curves which has just been remarked upon. The extent of the rise in the several groups, taken in order from south to north, is in the low region 5°·9, 9°·8, 19°·4, 22°·8, 27°·5, and 38°·8, and in the high region 11°·1, 14°·9, 24°·0, and 32°·0. But the evident system which pervades these ranges, and which is distinguishable as well amongst members of a single group as between different groups, will be most readily apprehended by consideration of the map, Plate LXVIII., which exhibits the ranges for individual stations. The principal characteristics of the distribution of ranges are, increase with increasing latitude, and increase with increasing distance from the sea.

233. Following the maximum, a marked depression of temperature attends the monsoon to its end, after which the temperature declines to the winter minimum. But in the latter and waning half of the monsoon the depression is partially recovered both in the Konkan and western part of the Deccan and in Guzerat, the small rise of temperature that then occurs reaching its climax in October in the two first-named districts, and in September in the last. It will be seen from the form of the curves presently to be described that a counterpart to this rise of temperature is found in other parts of the country in the shape of a diminished rate of seasonal fall, and that everywhere the phenomenon is due to increased radiation from the sun following upon the removal of monsoon influence.

234. A rough endeavour has been made to exhibit the cooling influence of the monsoon, in different parts of the country, by assuming the dry season's movements of the thermometer —from November to April—to be the reverse of those which would occur from April to November if the typical progression of the seasons was not interrupted by the monsoon. On this assumption the dotted portion of the curves, for the several groups of stations, of annual variation of temperature (figures 709 to 721) have been constructed; and the artificial curves thus formed in continuation with the actual curves for November to April are seen at a glance to be fair representatives of the typical annual variation curve in countries which have no specially rainy season.

235. We may now regard the depression of the actual below the artificial curves for the half year which includes the monsoon months as measuring roughly the effect of monsoon rain and monsoon cloudiness in depressing the temperature below what it assumably would have been if there were no monsoon. It would seem from the greater magnitude of the loops enclosed within the two curves that the absolute summer heat is more considerably tempered by the monsoon in Lower Sind, Malwa, and Guzerat than farther south, and more in the Deccan than in the Konkan; hence we conclude that the depression of temperature caused by the monsoon is to a much greater extent an effect of diminished solar radiation owing to monsoon cloudiness than of direct cooling by monsoon rain falling from a cool region aloft; for the rains are excessively more copious in the Konkan and on the edge of the Ghauts than elsewhere, and the annual ranges of temperature—which may be taken as rough measures of the capacity of the different districts to be affected by solar radiation—follow the same order as the magnitudes of the loops, viz., are least in the Konkan, next in the Deccan, and largest in the remaining (northern) parts of the Presidency. At Jacobabad, our most northerly station, where the loop is again smaller, it may well be that the monsoon cloudiness is less dense and persistent than farther south,—in other words, that it is near the edge of the monsoon region. It will be seen shortly that the unusual character of the prevalent winds of that district, during the monsoon, lends support to this supposition. The depression, it will be observed, increases until about the middle of July, or a little later, when the monsoon is at its height. The last curve of Plate LXIX. (figure 721) shows the average movements for all our full-year stations of the thermometer from month to month, and is constructed from the numbers at the foot of Table 148.

Winds of the Presidency.

236. Except for Goa and Bombay, all our wind occurrences have been abstracted from registers furnished by the Medical Department; and all, except those for the four military stations where there are observatories, are for short periods varying from a few months to three years. The registers indeed extend over much longer periods, but only a few seemed to have been kept with such care as to entitle them to any weight, the credibility of the great bulk of them being marred by an extravagant uniformity which is not found in the registers kept by trained observers at the four military stations. In selecting, those only were rejected which individually bore signs of untrustworthiness; and the remainder are, in what follows, treated with perfect impartiality, being left to exercise such weight as they inherently possess, and as is evidenced by the mutual support which the results derived from them afford to each other.

237. In the following statement are specified the stations, periods, and hours of observation, for which observations of occurrence of wind from different directions have been made use of in the present compilation.

Consecutive No.	Geographical District.	Station.	Period of Observation.	Hours of Observation.	Remarks.
1	Sind	Rohri	May to November 1868	6, 10, 16, and 22	17 days only for the month of May.
2		Jacobabad	September to November 1867	Do.	
3		Mehar	September to November 1867	Do.	
		Do.	June to August 1868	Do.	
4		Thárú Sháh	July 1868	6, 10, and 16.	
		Do.	August 1868	6, 15, and 18.	
5		Sehwan	August to November 1867	6, 10, 16, and 22	15 days only for the month of August. 17 „ „ September.
6		Tando Alahyar	September to November 1867	6 and 18.	
		Do.	May 1868	Do.	
		Do.	June to November 1868	6, 10, 16, and 22.	
7		Mitti	September to November 1867	10.	
		Do.	August to October 1868	Do.	
		Do.	August to October 1869	Do.	
8		Kurrachee	January to November 1856	9½ and 15½.	
		Do.	January 1857 to December 1864	Do.	
		Do.	April 1865 to September 1867	Do.	
		Do.	March 1868 to October 1872	Do.	
9	Guzerat	Deesa	June 1856 to June 1860	Do.	
		Do.	November 1860 to October 1867	Do.	
		Do.	February 1868 to November 1872	Do.	
10		Ahmedabad	May to November 1868	6, 10, 16, and 22	17 days only for the month of May. 15 „ „ November.
		Do.	May and June 1869	Do.	17 days only for the month of May.
		Do.	August to November 1869	Do.	15 days only for the month of November.
11		Baroda	January 1871 to October 1872	Do.	
12		Gogo	April 1867	Do.	
		Do.	September to November 1867	Do.	

Consecutive No.	Geographical District.	Station.	Period of Observation.	Hours of Observation.	Remarks.
13		Tungár Hill	May to October 1866	6, 10, 16, and 22.	
		Do.	March to June 1867	Do.	15 days only for the month of Ma
14		Matheran	July 1856 to June 1858	6, $\frac{14+18}{2}$	
		Do.	October 1858 to March 1859	Do.	
		Do.	May 1859 to June 1860	6, 10, 16, and 22.	
	Konkan	Do.	October 1860 to June 1861	Do.	
15		Bombay	June 1867 to May 1874	24 hours.	
16		Dápoli	September to December 1867	6, 10, and 16.	
17		Goa	April 1860 to November 1867	9, 12, 15, and 21.	
		Do.	December 1868 to May 1869	Do.	
		Do.	January 1870 to December 1873	Do.	
18		Násirabad	April to December 1862	6, 10, 16, and 22.	
		Do.	May to July 1864	Do.	
19		Nimach	January to August 1862	Do.	
20	Malwa	Mehidpur	September and October 1867	Do.	
21		Mhow	January to August 1862	Do.	
		Do.	September 1862	10 and 22.	
		Do.	October 1862 to November 1864	6, 10, 16, and 22.	
22		Málegaon	September and October 1867	Do.	
		Do.	June 1872	6, 10, and 16.	
23		Saptasring	March 1871 to March 1872	6, 10, 16, and 22.	
24		Násik	January to March 1866	Do.	
		Do.	April and June 1866	6, 10, and 16.	
		Do.	May 1866	6, 10, 16, and 22.	
		Do.	July to December 1866	Do.	
25		Ahmednágar	September to November 1867	Do.	
		Do.	May to November 1868	Do.	17 days only for the month of May.
26		Kirkee	January 1862 to December 1863	Do.	
		Do.	January to March 1865	Do.	
27	Deccan	Poona	January 1856 to November 1872	9½ and 15½.	
28		Kolhápur	September to November 1867	6, 10, 16, and 22	15 days only for the month of November.
		Do.	June to August 1868	Do.	
		Do.	September to November 1868	10 and 22.	
29		Belgaum	January 1856 to November 1872	9½ and 15½.	
30		Sholápur	September to November 1867	6, 10, 16, and 22.	
		Do.	May 1868	Do.	
		Do.	June 1868	6, 10, and 16.	
		Do.	July 1868	6, 10, 16, and 22.	
		Do.	August 1868	22.	
		Do.	September to December 1868	6, 10, 16, and 22.	
		Do.	February to June 1869	Do.	
		Do.	August to December 1869	Do.	
31		Purandhar	June to December 1856	6, 10, and 16.	
		Do.	January to December 1857	6, 10, 16, and 22.	
		Do.	January 1858 to April 1859	6, 10, and 16.	
32	Hill Stations (Deccan)	Mandhardeo	July to October 1863	6, 10, 16, and 22.	
33		Mahableshwar	January to December 1856	Do.	
		Do.	January to June 1859	6, 10, and 16.	
		Do.	August 1859	Do.	
		Do.	September 1859 to December 1860	6, 10, 16, and 22.	

238. And in Table 149 are shown the numbers of occurrences of winds from each of the sixteen principal directions, including calms, and the total number of observations in each month at each station.

TABLE 149.

Station.	Directions $\theta =$	N 0 0	NNE 22 30	NE 45 0	ENE 67 30	E 90 0	ESE 112 30	SE 135 0	SSE 157 30	S 180 0	SSW 202 30	SW 225 0	WSW 247 30	W 270 0	WNW 292 30	NW 315 0	NNW 337 30	Calm.	Variable. Limits not specified.	Total, excluding indefinite Variables.
ROHRI.	May	17		16		8		11		10		3		2		1				68
	June	11		17		30·5		39		5		10		6·5		1				120
	July	14		27		23		38		6		12		4						124
	August	12		30		27·5		32		11·5		10		1						124
	September	5		22		25		40		10		18								120
	October	12		28		37		38		4		5								124
	November	4		59				2		4		31		4		16				120
JACOBABAD.	September					1		79		37		1				1		1		120
	October	27		22		1		12						1		57		4		124
	November															117		3		120
MEHAR.	June							111										9		120
	July	2		2		4		115												124
	August					5		70										49		124
	September			4		112										1		3		120
	October	87		16		5		3		4						9				124
	November	114		4												2				120
THÁRUSHÁH.	July			2		3		29		10		22		2				25		93
	August	2				4		25		24		2		2				34		93
SEHWAN.	August	6				1		4		11		38								60
	September	3				1				8		29		24		1		2		68
	October	10										18	1	35		46		14		124
	November	70												18		32				120
TANDO ALÁHYAR.	May											16	37	1	8					62
	June			3	1	8	5	4			72	19	7	1						120
	July			2	2						23	73	16	8						124
	August			12							8	64	40							124
	September			6	4		1	31	4	1	1	21	105	5	1					180
	October	1	23	44	5		7	19		27			4	45	7		4			186
	November		28	28	4	1	14	16		34	3	7			25		20			180
MITTI.	August					3						36		17				6		62
	September	1		3						15		17		13				11		60
	October	17		11		2		2		4		23		1				2		62
	November	5		16								9								30
KURRACHEE.	January February March April May June July August September October November December	*See* Part II., Table 124.																		

TABLE 149—*continued.*

Station.	Directions	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.	Variable. — Limits not specified.	Total, excluding indefinite Variables.
	$\theta =$	0° 0′	22° 30′	45° 0′	67° 30′	90° 0′	112° 30′	135° 0′	157° 30′	180° 0′	202° 30′	225° 0′	247° 30′	270° 0′	292° 30′	315° 0′	337° 30′			
DEESA.	January	*See* Part II., Table 123.																		
	February																			
	March																			
	April																			
	May																			
	June																			
	July																			
	August																			
	September																			
	October																			
	November																			
	December																			
AHMEDABAD.	May											16		92		22		6		136
	June	1		3								189		23		23		1		240
	July											124								124
	August											247		1						248
	September											218		22						240
	October	2		62		5						73		148		20				248
	November					14								37		7				120
BARODA.	January	89		16		107								36						248
	February	124		3		34				1				64						226
	March	69		9		30		1		15		2		118		4				248
	April	46		2		15		3		37		3		134						240
	May	21				3				91		4		129						248
	June	3				3				115		1		118						240
	July									118		3		127						248
	August	1				4				118		2		123						248
	September	32		3		15				82		3		94		11				240
	October	55		3		68				15		1		95		11				248
	November	1				91				2				26						120
	December	25		1		90		1		3				4						124
GOGO.	April	13		4		7				29		32				35				120
	September			25				34				39				16				111
	October	16		19		4		22		5		47				7				120
	November	2		44				24				50								120
TUNGÁR HILL.	March	1		30		1										28				60
	April	22		23												75				120
	May	22		30		2		17		12		8		10		147				248
	June	3		44		54		2		1		88		35		1				228
	July	1		2		1				26		82		3		1				116
	August									42		67		15						124
	September	15		7						14		58		13		13				120
	October	69		26		20		3		3		2				1				124

TABLE 149—*continued.*

Station.	Directions θ =	N 0 0	NNE 22 30	NE 45 0	ENE 67 30	E 90 0	ESE 112 30	SE 135 0	SSE 157 30	S 180 0	SSW 202 30	SW 225 0	WSW 247 30	W 270 0	WNW 292 30	NW 315 0	NNW 337 30	Calm.	Variable. Limits not specified.	Total, excluding indefinite Variables.
MATHERAN.	January	147		84	1·5	104		3	0·5	1		11·5	0·5	39·5		33·5		8		434
	February	137	0·5	41	7	68·5	0·5							78		57·5		4	2	394
	March	67	1	39·5	3·5	56·5	1	2		1		4		82	3	171·5		2		434
	April	46	0·5	56·5	2	46		2		6	1	0·5		101·5	1	102		3		359
	May	16	0·5	16	2	44					3	70·5	8·5	119		209·5		1		496
	June			4	2							381·5	16·5	35		36		2		480
	July											187·5	49	7·5		4				248
	August									44		174	15	15						248
	September			7		1				8		179·5		37·5		7				240
	October	21·5		88·5	39·5	98		24				87·5		44·5		38·5			2	422
	November	34·5		108	2	206·5		14	2·5	4		3		6·5		37				418
	December	57·5		94·5	3	160		29	2·5	0·5		12·5		26·5		48				434
BOMBAY.		The coefficients given in Table 150 are derived from the numbers yielded by seven years' registrations of Robinson's anemometer.																		
DÁPOLI.	September											90								90
	October	24		1		41						1		13		8			5	88
	November	5		15		47				5						18				90
	December	6		7		44				4				23		9				93
GOA.	January	13	13	24	61	412	79	51	29	4	1	3	20	382	204	51	41	101		1,489
	February	15	28	16	40	202	51	20	21		1		31	363	304	96	64	100		1,352
	March	14	13	16	17	76	25	22	14	8	2	1	64	412	435	179	100	90		1,488
	April	5	12	4	16	19	10	14	11	5	5	17	85	446	535	212	41	63		1,500
	May	8	4	3	9	6	6	8	10	24	13	32	75	447	648	253	31	34	1	1,611
	June	1	6	8	9	14	18	52	96	41	35	57	196	442	303	42	16	104	1	1,439
	July	1		1	8	9	9	8	10	8	12	58	245	517	502	34	11	55		1,488
	August	5	6	12	4	5	6		6	4	1	27	152	596	474	84	31	75		1,488
	September	9	11	17	16	49	12	23	23	6	7	20	136	408	425	122	30	126		1,440
	October	4	17	21	52	208	73	54	54	11	14	18	98	290	289	77	25	183		1,488
	November	4	14	31	67	491	138	67	37	7	3	2	53	188	173	50	14	101		1,440
	December	8	13	39	91	611	130	50	26	5	8	2	34	288	129	40	15	123		1,612
NÁSIRABAD.	April		7	10	3	1				1	13	12	29	14	23	5	2			120
	May	1	3	24	3	1		9		2	5	48	34	55	22	34	7			248
	June	1	1	21	4	3	6	7			3	31	27	75	29	32				240
	July	1		17		4		7		1		68		77		73				248
	August			4		3		2				46		46		23				124
	September		2	9	6		11	3			8	19	14	22	17	8	1			120
	October		6	7	7	1	2	1		2	7	14	21	23	15	12	6			124
	November	1	17	17	22	1	2	1			16	7	16	2	4	12	2			120
	December	2	12	40	24	1	11	2		1	10	4	2	1	8	3	3			124
NIMACH.	January	33		30		20		1				3		8		29				124
	February			25		18		10				18		14		27				112
	March			46				14				33		1		30				124
	April			2				4				43		30		41				120
	May							6				67		39		12				124
	June			5				16				54		41		4				120
	July			1				1				75		41		6				124
	August			2				2				58		45		17				124

TABLE 149—*continued.*

Station.	Directions	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.	Variable. — Limits not specified.	Total, excluding indefinite Variables.
	$\theta =$	0 0	22 30	45 0	67 30	90 0	112 30	135 0	157 30	180 0	202 30	225 0	247 30	270 0	292 30	315 0	337 30			
MEHIDPUR.	September	2		8				3		2		22		31		46		5		119
	October -	7		61		2		20		1		15		4		11		3		124
MHOW.	January -	19		111		51		85		12		40		45		9				372
	February	18		62		48		114		11		59		13		15				340
	March -	16		41		21		85		42		115		37		15				372
	April -	8		8		59		26		53		102		57		47				360
	May -			7	1	54		18		62		86		62		82				372
	June -			40				53		68		123		51		25				360
	July -	2		24		6		17		47		216		51		9				372
	August -	13		2				6		4		160		108		77				370
	September	9		15				3		1		137		102		28				295
	October -	22		22		16		37		16		134		104		21				372
	November			84		74		168		3		26		1		4				360
	December	1		44		31		131		16		20		3		2				248
MÁLEGAON.	June -	1		14				4				26		19		26				90
	September	26		36				4		12		4		18		13		7		120
	October -	22		41				2		12		1		21		15		10		124
SAPTASRING.	January -	19	1	3		2	3	2	1	15	5	12	11	23	3	9	4	11		124
	February	19	3	14	4	8	2	9		6		8		15	2	19	2	5		116
	March -	51	3	45	11	14	2	3		3		2	2	10	13	49	13	11		232
	April -	10	10	6	2			1	1		20	5	7	8	13	12	18	7		120
	May -	10	13	1	9	1	9	3	8	6	21	2	13	2	7		16	3		124
	June -	17	6	1		3	3		6	12	17		10	23	10		12			120
	July -	3			2	1			1	4	12		19	38	36		8			124
	August -	4	2		1				2	6	10		37	41	15		5	1		124
	September	14	10	1					3	7	4		15	29	19		14	4		120
	October -	27	15	6	8	11				2	3		1	10	9	5	15	12		124
	November	12	4	1	6	5	5	1	7	14	11	9	10	12	4	2	5	12		120
	December	9		4			2	4	2	18	12	27	6	11	1	18	1	9		124
NÁSIK.	January -	6		31		69		13		2				1		2				124
	February	2		22		42		6				2		27		11				112
	March -	8		16		52		7		5		2		23		11				124
	April -	9		11		37		7		1		1		16		6			2	88
	May -	21		29		15		9				1		26		19			4	120
	June -					31		5		2		39		20		11			2	88
	July -			1		30		6				30		52		5				124
	August -			1		4		1				27		86		5				124
	September	6										12		82		20				120
	October -	7		11		20		8				19		50		9				124
	November	11		5		28		2		3		4		66		1				120
	December	8		22		37		3		5		23		26						124
AHMEDNÁGAR.	May -	10		6		4		6		2		14		12		14				68
	June -	26				12		1		25		19		26		11				120
	July -	13				19				18		20		44		10				124
	August -	27				15				9		13		36		24				124
	September	34				24		5		20		57		36		64				240
	October -	70		18	1	27		4		26		43		20		39				248
	November	43		25		16		17		42		29		41		27				240

TABLE 149—*continued.*

Station.	Directions	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.	Variable. — Limits not specified.	Total, excluding indefinite Variables.
	θ =	0 ° 0	22 ° 30	45 ° 0	67 ° 30	90 ° 0	112 ° 30	135 ° 0	157 ° 30	180 ° 0	202 ° 30	225 ° 0	247 ° 30	270 ° 0	292 ° 30	315 ° 0	337 ° 30			
KIRKEE.	January		34	118	15	22						1	1	58	31	86	6			372
	February	1	18	152	5	7	9						1	98	1	44				336
	March	5	5	138	7	5	3			1		1	3	93	2	102	7			372
	April		1	108	9		7	1				6		38	14	56				240
	May			67			2						1	119	4	55				248
	June			38					1		69	29	14	8		81				240
	July			14							48	46	28	2		110				248
	August											39	68.	17		124				248
	September			1								18	73	28		120				240
	October		17	32	28							2	2	41	1	124	1			248
	November		19	35	47	8								8	3	120				240
	December	1	33	141	49	1									12	9	2			248
POONA.	January	*See* Part II., Table 121.																		
	February																			
	March																			
	April																			
	May																			
	June																			
	July																			
	August																			
	September																			
	October																			
	November																			
	December																			
KOLHÁPUR.	June			8								107		4				1		120
	July											122		2						124
	August									19		90		15						124
	September			2						42		126		1				9		180
	October	5		41		21		16		18		64		11		2		8		186
	November	6		59		19		9				19		5		2		1		120
BELGAUM.	January	*See* Part II., Table 120.																		
	February																			
	March																			
	April																			
	May																			
	June																			
	July																			
	August																			
	September																			
	October																			
	November																			
	December																			
SHOLÁPUR.	February	8		5		46		5		2		1		45						112
	March					50		6				10		58						124
	April					30		1				10		78		1				120
	May	7		1		54				2		7		121						192
	June	1		1		3		1				11		161						210
	July					7								112		5				124
	August			2		1						10		142						155
	September	3		6		6				6		53		272		13			1	359
	October	14		29		106		2		4		38		158		21				372
	November	42		80		191		4				3		33		7				360
	December	9		18		192		7						22						248

TABLE 149—*continued.*

Station.	Directions	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.	Variable. Limits not specified.	Total, excluding indefinite Variables.
	$\theta =$	° ° 0	° ′ 22 30	° ′ 45 0	° ′ 67 30	° ′ 90 0	° ′ 112 30	° ′ 135 0	° ′ 157 30	° ′ 180 0	° ′ 202 30	° ′ 225 0	° ′ 247 30	° ′ 270 0	° ′ 292 30	° ′ 315 0	° ′ 337 30			
PURANDHAR	January -		19	85	12	124		6				7		1		46	1	9		310
	February-			74	4	81		1				18		1		97		4		280
	March -	7		60		100						31		19		69		24		310
	April -	26		37		93		12		5		39		26		41		20	1	299
	May -	1		17		43		8				72		29		27		20		217
	June -			2		45		26		2		126		87		15	1	25	1	329
	July -					12		12	4	14		185	1	78		8		22	5	336
	August -	1		2				10		31		175		69		25		21	7	334
	September	1		25		6		9		15		107	1	53	2	59	1	41	9	320
	October -	4		72		61		44		7		25		10		47		70	1	340
	November			64	3	108		90		1	1	13		5		4		40	1	329
	December			67		178		51				11				19	9	4		339
MANDHARDEO.	July -											35		89						124
	August -					12		4				76		32						124
	September			12		4						20		46		38				120
	October -	9		55		36						16		8						124
MAHABLESHWAR.	January -	26		22		142		21		16		29		55	1	29				341
	February-	8		1		77		18		5		19		164		24				316
	March -	20		15		65	1	1		4		13		181	2	39				341
	April -	27	1	25		90	1	6		9		1		74	7	89		1		330
	May -	74		8		52	1	5		2		10		127	3	59				341
	June -	1		1		3		6		2		222		75		20				330
	July -											248								248
	August -											341								341
	September			33								283		46		2				364
	October -	39		32		142		9		5		20		77		48				372
	November	8		10		294	3	9		3		1		19		12	1			360
	December	6		24		272	2	18		1		9		36		4				372

239. The treatment to which the observations have been subjected is the same that has been described in paragraphs 193 to 196, except that instead of calculating the coefficients of the formula

$$r\frac{n_\theta}{N} = 1 + c_1 \cos(\theta - \alpha_1) + c_2 \cos(2\theta - \alpha_2)$$

the calculations have extended only to the determination of the coefficients a_1, b_1, a_2, b_2 of the equivalent formula

$$r\frac{n_\theta}{N} = 1 + a_1 \cos\theta + b_1 \sin\theta + a_2 \cos 2\theta + b_2 \sin 2\theta. \qquad (3)$$

The values of the coefficients are shown in the following table.

TABLE 150.

VALUES of the COEFFICIENTS a_1, b_1, a_2, b_2 of the FORMULA (3), calculated from the NUMBERS in TABLE 149 for each Month of the Year, and for the whole Year.

Station.	January.				February.				March.				April.				May.				June.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
Rohri																	+·27	+·65	+·50	+·21	−·26	+·93	−·35	−·22
Jacobabad																								
Mehar																					−1·31	+1·31	·00	−1·85
Tháru Sháh																								
Sehwan																								
Tando Aláhyar																	−·72	−1·74	−1·06	+1·18	−1·39	−·50	+·55	+1·18
Mitti																								
Kurrachee	+·34	+·39	−·51	+·37	+·23	−·41	−·54	+·06	+·11	−1·10	−·77	+·05	−·04	−1·36	−·73	+·07	−·11	−1·59	−·98	+·09	−·25	−1·57	−·94	+·28
Deesa	+·82	+·18	+·21	+·02	+·68	−·33	−·06	+·08	+·27	−·71	−·30	−·02	+·03	−1·07	−·37	+·03	−·89	−1·26	−·14	+·85	−·95	−·64	+·25	+·91
Ahmedabad																	+·06	−1·75	−1·35	−·09	−·95	−1·42	−·18	+1·41
Baroda	+·81	+·66	−·44	+·13	+1·11	−·25	+·24	+·03	+·49	−·69	−·52	+·05	+·05	−·98	−·55	−·02	−·59	−1·04	−·16	+·03	−·94	−·96	−·02	+·01
Gogo													−·18	−·63	+·58	+·02								
Tungár Hill									+1·40	+·08	·00	+·07	+1·52	−·61	+·37	−·87	+·95	−·68	+·18	−1·02	−·26	−·10	−·75	+1·13
Matheran	+1·01	+·44	+·02	+·28	+1·06	−·07	−·07	−·06	+·99	−·55	−·35	−·60	+·89	−·48	−·58	−·25	+·46	−1·07	−·59	−·47	−1·06	−1·42	−·19	+1·52
Bombay	+1·43	−·12	+·62	−·37	+1·35	−·34	+·44	−·59	+1·04	−·75	+·12	−·80	+·74	−1·04	−·17	−·75	+·13	−1·46	−·78	−·26	−·72	−1·17	−·70	+·56
Dápoli																								
Goa	+·15	−·04	−1·31	−·35	+·36	−·64	−1·14	−·50	+·48	−1·19	−1·02	−·70	+·45	−1·51	−1·15	−·72	+·46	−1·61	−1·12	−·80	−·20	−1·21	−·94	−·22
Násirabad													−·06	−1·10	−·62	+·60	+·01	−1·14	−·68	+·33	+·08	−1·17	−1·01	+·11
Nimach	+1·14	+·18	+·08	+·05	+·30	−·05	−·57	+·11	+·33	−·05	−·02	+·56	−·05	−1·42	−·50	·00	−·69	−1·46	−·63	+·79	−·73	−1·12	−·68	+·65
Mehidpur																								
Mhow	+·19	+·59	−·35	+·31	−·36	+·63	−·19	−·59	−·69	−·10	·00	+·30	−·54	−·44	−·31	+·21	−·39	−·58	−·29	−·03	−·81	−·54	+·09	+·47
Málegaon																					+·18	−·96	−·40	+·22
Saptasring	−·08	−·73	+·08	+·13	+·52	−·10	·00	−·09	+1·15	−·08	+·14	−·12	+·47	−·71	+·35	+·05	−·02	−·12	+·44	+·18	+·02	−·71	+·26	+·04
Násik	+·29	+1·58	−1·00	+·26	+·35	+·46	−1·20	+·12	+·25	+·58	−1·00	·00	+·32	+·65	−·98	−·02	+·80	+·03	−·33	+·03	−·58	−·93	−·66	+·52
Ahmednágar																	+·23	−·57	−·12	·00	−·08	−·58	+·22	+·12
Kirkee	+1·06	−·10	−·46	+·23	+·92	+·02	−·61	+·70	+1·00	−·32	−·51	+·21	+·98	−·02	−·49	+·41	+·70	−·91	−1·00	+·09	−·05	−·80	+·26	+·37
Poona	−·22	+·44	−·14	−·24	+·30	−·11	−·13	−·20	+·64	−·56	−·04	−·27	+·80	−·56	+·17	−·39	+·77	−1·09	−·16	−·46	+·05	−1·46	−·73	+·47
Kolháp ur																					−1·17	−1·23	−·07	+1·92
Belgaum	−·33	+·94	−·62	−·06	−·10	+·44	−·57	+·20	·00	−·16	−·60	+·37	−·01	−·48	−·46	+·48	−·06	−1·47	−·84	+·22	−·51	−1·64	−1·11	+·70
Sholápur					+·09	+·13	−1·45	+·02	−·18	−·17	−1·74	+·06	−·12	−·92	−1·80	+·13	+·01	−·74	−1·73	+·08	−·06	−1·56	−1·55	+·10
Purandhar	+·69	+1·09	−·77	+·39	+·78	+·40	−·61	−·02	+·49	+·34	−·72	+·14	+·27	+·30	−·58	+·15	−·23	−·35	−·65	+·50	−·59	−·74	−·79	+·58
Mandhardeo																								
Mahableshwar	+·06	+·44	−·90	·00	−·03	−·66	−1·44	−·14	+·26	−·84	−1·31	−·08	+·56	−·19	−·81	−·44	+·64	−·68	−·62	−·29	−·89	−1·44	−·45	+1·19

TABLE 150—*continued.*

Station.	July.				August.				September.				October.				November.				December.				Year.			
	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2	a_1	b_1	a_2	b_2
Rohri	− ·13	+ ·91	− ·11	+ ·02	− ·13	+1·02	− ·08	+ ·13	− ·51	+ ·93	− ·17	·00	− ·04	+1·29	− ·34	− ·08	+ ·49	+ ·10	+ ·07	+1·20								
Jacobabad									−1·55	+ ·92	+ ·60	−1·32	+1·20	− ·26	+ ·40	− ·76	+1·38	−1·38	·00	−1·95								
Mehar	−1·24	+1·39	− ·02	−1·83	− ·80	+ ·88	− ·08	−1·13	+ ·06	+1·90	−1·87	+ ·05	+1·59	+ ·19	+1·39	+ ·06	+1·97	+ ·02	+1·90	+ ·03								
Tháru Sháh	− ·96	+ ·16	+ ·11	− ·11	− ·88	+ ·39	+ ·43	− ·49																				
Sehwan					−1·16	− ·77	+ ·53	+1·13	− ·73	−1·30	− ·41	+ ·82	+ ·47	−1·31	− ·41	− ·44	+1·54	− ·68	+ ·87	− ·53								
Tando Aláhyar	−1·24	−1·29	− ·07	+1·68	− ·96	−1·24	− ·36	+1·77	− ·85	− ·95	+ ·88	− ·77	+ ·18	+ ·08	− ·15	+ ·38	+ ·19	+ ·25	+ ·43	+ ·02								
Mitti					− ·82	−1·27	− ·63	+1·16	− ·80	− ·76	+ ·10	+ ·67	+ ·10	− ·20	+ ·58	+1·03	+ ·66	+ ·33	+ ·33	+1·67								
Kurrachee	·00	−1·60	− ·91	+ ·01	+ ·08	−1·59	− ·89	− ·07	+ ·02	−1·57	− ·94	− ·04	− ·03	−1·20	− ·64	+ ·15	+ ·27	− ·33	− ·51	+ ·28	+ ·25	+ ·36	− ·55	+ ·47	+ ·07	− ·96	− ·74	+ ·14
Deesa	−1·19	− ·99	+ ·20	+1·10	−1·02	−1·08	+ ·06	+1·02	− ·43	− ·93	− ·16	+ ·36	+ ·06	− ·27	− ·19	+ ·05	+ ·53	+ ·35	− ·04	+ ·08	+ ·71	+ ·20	+ ·26	+ ·07	− ·11	− ·55	− ·02	+ ·38
Ahmedabad	−1·41	−1·41	·00	+2·00	−1·41	−1·42	− ·01	+1·99	−1·20	−1·47	− ·18	+1·82	− ·29	−1·68	−1·22	+ ·43	+ ·81	+ ·26	− ·85	+ ·92								
Baroda	− ·95	−1·04	− ·07	+ ·02	− ·95	− ·97	− ·06	+ ·02	− ·37	− ·72	+ ·04	− ·04	+ ·40	− ·27	− ·75	− ·06	− ·02	+1·08	−1·90	·00	+ ·35	+1·41	−1·06	·00	− ·05	− ·31	− ·44	+ ·01
Gogo									− ·45	+ ·09	·00	+ ·31	− ·32	− ·09	+ ·28	+ ·62	− ·32	− ·21	+ ·03	+ ·21								
Tungár Hill	−1·39	−1·02	+ ·40	+1·43	−1·44	−1·01	+ ·44	+1·08	− ·43	− ·97	+ ·27	+ ·87	+1·31	+ ·62	+ ·84	+ ·39												
Matheran	−1·20	−1·52	− ·34	+1·76	−1·39	−1·22	+ ·15	+1·49	−1·04	−1·36	− ·25	+1·50	+ ·13	+ ·38	− ·80	+ ·67	+ ·57	+1·25	− ·84	+ ·29	+ ·59	+ ·84	− ·59	+ ·14	+ ·08	− ·40	− ·37	+ ·52
Bombay	− ·60	−1·69	−1·24	+ ·87	− ·30	−1·69	−1·31	+ ·50	+ ·04	−1·19	− ·83	− ·23	+ ·99	− ·10	+ ·07	− ·35	+1·10	+ ·34	− ·02	+ ·08	+1·25	+ ·18	+ ·18	·00	+ ·54	− ·75	− ·30	− ·11
Dápoli									−1·41	−1·41	·00	+1·00	+ ·67	− ·51	− ·68	− ·14	+ ·52	+1·00	− ·82	− ·07	+ ·29	+ ·42	−1·23	− ·04				
Goa	+ ·28	−1·68	−1·39	− ·23	+ ·27	−1·66	−1·36	− ·40	+ ·27	−1·25	−1·12	− ·46	+ ·07	− ·44	−1·03	− ·37	+ ·02	+ ·44	−1·28	− ·34	+ ·09	+ ·52	−1·38	− ·20	+ ·22	− ·86	−1·18	− ·45
Násirabad	+ ·09	−1·26	− ·64	+ ·04	− ·24	−1·41	− ·79	+ ·40	− ·15	− ·80	+ ·80	+ ·29	+ ·08	−1·01	− ·65	+ ·33	+ ·36	+ ·03	− ·14	+ ·93	+ ·66	+ ·76	− ·21	+ ·93				
Nimach	− ·78	−1·56	− ·66	+1·11	− ·47	−1·53	− ·73	+ ·66																				
Mehidpur									+ ·35	−1·20	− ·45	− ·32	+ ·52	+ ·59	+ ·03	+ ·73												
Mhow	−1·00	− ·94	− ·04	+1·15	− ·28	−1·46	− ·51	+ ·44	− ·41	−1·40	− ·62	+ ·82	− ·45	− ·83	− ·44	+ ·53	− ·43	+1·28	− ·40	− ·34	− ·71	+1·09	− ·14	− ·56	− ·49	− ·22	− ·27	+ ·23
Málegaon									+ ·72	− ·03	+ ·33	+ ·38	+ ·77	− ·03	+ ·21	+ ·40												
Sáptasring	+ ·03	−1·50	− ·93	− ·14	− ·24	−1·49	− ·89	+ ·32	+ ·42	−1·03	− ·17	− ·07	+1·03	− ·02	+ ·30	+ ·05	− ·29	− ·33	+ ·17	+ ·23	− ·48	− ·74	+ ·33	+ ·28	+ ·21	− ·63	+ ·01	+ ·08
Násik	− ·34	− ·67	−1·32	+ ·32	− ·25	−1·66	−1·45	+ ·35	+ ·19	−1·74	−1·27	− ·13	+ ·03	− ·59	−1·02	+ ·21	+ ·12	− ·61	−1·33	+ ·10	·00	+ ·20	− ·81	+ ·68	+ ·10	− ·22	−1·03	+ ·20
Ahmednágar	− ·19	− ·74	− ·52	+ ·16	+ ·42	− ·74	− ·24	− ·18	+ ·13	− ·78	− ·05	− ·10	+ ·41	− ·28	+ ·39	+ ·15	+ ·04	− ·29	+ ·23	+ ·08								
Kirkee	·00	−1·18	+ ·10	+ ·03	+ ·27	−1·57	− ·52	− ·38	+ ·37	−1·13	− ·66	− ·41	+1·10	− ·63	− ·40	− ·47	+1·22	− ·10	− ·63	− ·67	+1·31	+1·13	− ·15	+1·45	+ ·74	− ·47	− ·42	+ ·13
Poona	− ·32	−1·70	−1·08	+ ·48	− ·18	−1·66	−1·07	+ ·33	+ ·24	−1·42	− ·70	− ·08	+ ·27	+ ·21	− ·18	− ·16	− ·06	+1·41	− ·71	− ·14	− ·24	+1·14	− ·66	− ·44	+ ·17	− ·45	− ·45	− ·09
Kolhápur	−1·39	−1·42	− ·03	+1·97	−1·33	−1·27	+ ·06	+1·45	−1·44	− ·98	+ ·46	+1·42	− ·42	+ ·04	− ·10	+ ·94	+ ·49	+ ·79	− ·30	+1·12								
Belgaum	− ·62	−1·68	−1·08	+ ·89	− ·34	−1·75	−1·41	+ ·53	− ·17	−1·65	−1·35	+ ·30	·00	+ ·14	− ·61	+ ·22	+ ·14	+1·66	− ·87	+ ·22	− ·07	+1·41	− ·95	+ ·22	− ·17	− ·35	− ·87	+ ·36
Sholápur	+ ·06	−1·75	−1·92	− ·08	− ·07	−1·89	−1·85	+ ·15	− ·15	−1·71	−1·50	+ ·26	+ ·09	− ·39	−1·32	+ ·24	+ ·55	+1·11	−1·01	+ ·40	+ ·13	+1·52	−1·65	+ ·09				
Purandhar	− ·90	−1·14	− ·44	+ ·97	− ·85	−1·21	− ·22	+ ·85	− ·22	− ·89	− ·28	+ ·39	+ ·19	+ ·48	− ·35	+ ·04	− ·15	+1·23	− ·69	− ·09	+ ·15	+1·40	−1·01	+ ·01	− ·03	+ ·08	− ·59	+ ·32
Mandhardeo	− ·40	−1·83	−1·44	+ ·56	− ·91	−1·14	− ·71	+1·16	+ ·35	−1·24	− ·83	− ·10	+ ·59	+ ·90	+ ·56	+1·15												
Mahableshwar	−1·41	−1·41	·00	+2·00	−1·41	−1·41	·00	+2·00	− ·96	−1·23	− ·25	+1·73	+ ·38	+ ·25	− ·94	− ·03	+ ·07	+1·56	−1·69	− ·06	+ ·03	+1·39	−1·62	+ ·05	− ·22	− ·35	− ·76	+ ·46

240. By means of formula (3) and these numbers, have been calculated for each of the 16 principal directions, N., N.N.E, N.E., &c., for each month and each station, the values of the relative duration; and to represent these values, figures have been constructed in the following manner:—Taking the intersection of a vertical and a horizontal line representing the directions N., S., E., and W., as the centre of a system of polar coordinates, in which the angle θ is measured from the upward vertical direction by a right-handed rotation, the calculated values of the relative duration are set off in a radial direction for each of the 16 angles $22\frac{1}{2}°$, 45°, $67\frac{1}{2}°$, &c., and the successive points are then joined, with a free hand, forming a closed curve, which for the particular month and station shows the most important features of the variation, with respect to direction, of the duration of the wind. Negative values of the relative duration are set off in the opposite direction to positive values, and the corresponding parts of the curves are dotted instead of being drawn in continuous lines. The figures are drawn to a scale of half an inch to the unit of relative duration on the margins of the monthly temperature maps (Plates LV. to LXVI.); and arrows, flying with the wind, are also drawn on the maps with their points at the several stations, and having lengths equal to the resultants of the coefficients a_1 and b_1, such arrows showing with respect to which side of the compass the duration of the wind preponderates, and by what proportion of the average duration of all winds the preponderance is on that side; they show also the probable direction of maximum preponderance.* As explained before, this is only one, but the most interesting, of the elements which make up a complete exposition of the variation of the relative duration. The figures on the margins also have lines representing these resultants drawn from their centres; but they exhibit too many other particulars to admit of their being shown, without confusion, with their centres over the respective stations on the maps; for this reason only are they placed on the margins.

241. The resultants of the a_1, b_1 coefficients for each month of the year have also been curved in the usual manner—*i.e.*, positive values of a_1 being set off upward, and of b_1 to the right—to represent the annual variation of the direction and amount of the preponderance of the prevailing winds. The figures here referred to are numbered 722 to 754, the names of the respective stations being marked within or near the several figures. Our remarks on the winds of the Presidency will have reference chiefly, though not exclusively, to these figures.

242. Beginning with our most northerly region—Upper Sind—we observe that at Rohri the prevalent winds from June to October blow from directions between east and south-east, and in May and November from the north-east quadrant. This gives to the winds of the monsoon season so abnormal a character, as compared with that of the winds of the Presidency generally, that, if unsupported by the observations of neighbouring stations, but little weight could be attached to those of Rohri. We find, however, that both at Jacobabad in September, at Mehar from June to the beginning of September, and at Tháru Sháh in July and August, the prevalent winds blow also from the south-east quadrant, whilst at Sehwan, Tando Aláhyar, and Mitti, though possessing a larger south duration component than is usual further south and east, they blow from the north-east or

* Partly to avoid confusion, no arrows have been made for Kirkee, which is very near to Poona, and for which the observations are much less numerous than for the latter place.

west quadrant. As a general rule, between the monsoon and the winter months a westerly duration component is gradually changed into an easterly component, but at Rohri, Jacobabad, and Mehar this rule—so far as the figures show—is reversed; and a further characteristic which seems to distinguish the wind system of Upper Sind is that in October and November the winds of Jacobabad come from the north-west quadrant, and at Mehar from northward, also from northward at Rohri in November, whilst the winter direction in the Presidency generally is from the north-east quadrant. At Sehwan also the prevalent winds of October and November are, like those of Jacobabad, from north-west, the Upper Sind system being thus followed towards the winter, whilst the more general system is adhered to by the winds of the monsoon. On the other hand, Tando Alâhyar and Mitti both adhere to the general system in that winds from the north-east quadrant preponderate, though slightly, in November. When we come to compare the temperature and rain distributions with the prevalent winds, we shall see that the peculiarities of the winds of the Upper Sind district have counterparts in the temperature and rainfall phenomena. The direction of the wind at Kurrachee seems to be much influenced by the direction of the Mekran coast; for eight months of the year—March to October—the prevalent winds reach Kurrachee from almost due west, that is, in continuation of the Mekran coast line, and a westerly duration component exists in the winds of the preceding and following months, February and November, leaving only December and January with a small preponderance of north-east winds. The mountains which abut upon the district to north and north-east of Kurrachee also offer obstacles to the progress of the wind in that direction, which are absent on the relatively flat course to eastward.

243. From May to September at Deesa and Baroda, and from June to September at Ahmedabad, the prevalent direction of the wind is from the south-west quadrant, with a large south duration component; at Deesa from November to January, at Ahmedabad in November, and at Baroda in December and January, the preponderance of wind is from the north-east quadrant, and at Baroda in November from due east. Both at Deesa and Baroda the change from the winter to the monsoon character is by a left-handed rotation of the wind, with comparatively large resultant duration coefficients; and from the monsoon to the winter by a right-handed rotation, with relatively small resultant duration coefficients. The persistency with which the winds of Baroda yield a *large* east duration component from November to January may be due in some way to the proximity of the termination of the Vindya mountains; in this particular the winds of Baroda are at variance with those of Deesa, which yield a *small* east duration coefficient. For Gógo we have but four months' coefficients, each derived from single month's observations, viz., those of April and September to November. These, as compared with the typical winds of the Presidency for those months, are generally abnormal, those of September to November from southward appearing to be affected by the direction of the inlet of the Gulf of Cambay, and that of April being in advance, in respect of rotation from right to left, of the normal direction of that month.

244. For the Malwa plateau we have curves for Násirabad, April to December; for Nimach, January to August; for Mehidpur, September and October; and for Mhow, the full year. All that need be said of the two months' observations at Mehidpur is that they show the usual progression in the change of wind from September to October. At the three

other stations, so far as the curves show, the wind is westerly from March to October, and easterly from November to February, the maximum westerly coefficient belonging to the middle of the monsoon, and the maximum easterly to near midwinter. But Mhow has also a considerable south direction component in all months except January; and, on the other hand, the monsoon winds of Násirabad have an abnormal north direction component, being nearly due west instead of considerably south of west, as is the case at Nimach and Mhow. The contrast in this respect between the winds of those two stations will be reverted to later.

245. For the Deccan, we have curves—besides those for hill stations—for the full year for Násik, Kirkee, Poona, and Belgaum, and, with the exception of the month of January, for Sholápur. We have also incomplete curves for Málegaon, Ahmednágar, and Kolhápur. At all these stations westerly winds attain their maximum of duration in the middle of the monsoon, and, so far as the curves show, easterly winds near midwinter. Generally the monsoon winds deviate but little, if at all, to the south of west, but at Kolhápur they are from south-west. The months in which easterly winds prevail are, at Kirkee, December; at Poona, October to January; at Belgaum, October to March; and at Sholápur, November to February. As compared with the general progression of change of wind in the Deccan between the months November and May, that of the single year's winds at Násik exhibits a persistent lagging, which, until confirmed by further observations, we are disposed rather to regard as a peculiarity of the particular year (1866) than as representing a permanent characteristic of the wind variations of the district.

246. The hill stations, as well on the Deccan as in the Konkan, have south-west winds, with large resultant duration coefficients, during the months June to September, and east or south-east winds, also with large resultant duration coefficients, from November to January. The mode of progression in the change from the monsoon to the winter is similar at all the stations, but the reverse movement is much varied, though not so as to introduce into the curves features of greater prominence than the monsoon and winter excursions.

247. Of the curves of the stations in the Konkan, that of Bombay is almost an exact counterpart of that of Deesa; that of Goa is of the same form, but twisted in a right-handed direction through an angle of 45°; and that of Dápoli, considering that it represents only single month's observations, and that the station is on a low hill, is in fair agreement with those of Bombay and Matheran. The curves of Goa and Belgaum—the latter place about 50 miles to landward of the former, and on the Deccan plateau—show that the same winds have the same degree of preponderance at both places in the months May to September, but for the remaining months of the year the prevalent winds of Belgaum have an east duration component, which is in excess of that of the Goa winds by about unity of average duration; in other respects the two annual variations are closely approximate to each other throughout. The curve for the Saptasring Hill in the Násik district we make no remark upon; it is of very abnormal form, and the place is one of those which we have been unable exactly to localize.

248. *General view.*—To collect the general facts as regards different regions, we have in the low region, during the monsoon months June to September, south-west winds with

large resultant duration coefficients, prevailing from Dápoli northward to Tando Allá Yár in Sind. From November to January, or to December only, the prevalent winds have considerable north duration components and small east components. The change from monsoon to the winter is made by a right-handed rotation of the wind with relatively small resultant duration coefficients; and the reverse change is effected by a left-handed rotation with relatively large resultant duration coefficients. The direction of principal change of the wind in this region—that is, the direction along which the largest annual variation of the duration component is found—is south-west or north-east. In Upper Sind south-east winds decidedly prevail during the monsoon months June to September, and north-west or north winds during the early winter; and Sehwan must be classed with Upper Sind in the winter, and with Lower Sind during the monsoon. Proceeding from Dápoli southward to Goa we find the same annual law holding, but with this difference, that from October to January the north duration component is almost entirely absent, and later it is deficient as compared with Bombay and Deesa. On the coast of Sind the prevalent winds are westerly, with large west duration components from March to October, and easterly with small east duration components only in December and January; the direction of principal change is west by south or east by north. The winds of the Malwa plateau differ from those of Lower Sind, Guzerat, and the Konkan as far south as Dápoli, chiefly in these respects, that the direction of principal change is more nearly east or west than north-east or south-west, and the east direction components of the winter months are larger; there is also noticeable a persistent south duration component on the southern edge of the plateau, and a persistent deficiency of the same component on the northern edge of the plateau; at least this is so for eleven out of twelve months in the former case, and for seven out of nine months in the latter.

249. On the Deccan, at other than hill stations, the monsoon winds from June to September are from westward inland, and from a little south of west near the Ghauts, always with large relative duration coefficients. The winter winds are from eastward, also with large relative duration coefficients, and in this respect contrasting with the winter winds of the Konkan, Guzerat, and Lower Sind. The direction of principal change is east or west.*

250. At the hill stations both of the Deccan and Konkan, and also at Kolhápur, the monsoon winds are decidedly from the south-west, and with large coefficients; the easterly winds of the winter have larger coefficients and prevail longer than in the plains of the Konkan, and the extended prevalence is greater as we proceed eastward; for at Purandhar easterly winds prevail from October to April, at Mahableshwar and Matheran from October to January, and at Goa and Bombay only during December and January.

251. The mean values for different districts of the east relative duration coefficients for the month of October afford evidence that the monsoon winds give place to the easterly winds which follow, not all at the same time, but successively in different parts of the country. The mean coefficients are as follows: +·53 for Purandhar, Mándhardeo, Maha-

* Except for the monsoon months, the winds of Kirkee are so discordant, as compared with those of other low stations on the plateau, that we have given no weight to those of any but the monsoon months in the generalizations which we have attempted.

bleshwar, Matheran, and Tungár Hill; +·13 for Poona, Belgaum, and Kolhápur; —·32 for Málegaon, Násik, Ahmednágar, and Sholápur; —·35 for Bombay, Dápoli, and Goa; —·74 for Deesa, Ahmedabad, and Baroda; —·92 for Násirabad and Mhow, and —1·20 for Kurrachee. As the east component is, in all the districts considered, increasing at this season of the year, the interval between the time of change from a westerly to an easterly wind and the middle of October may be taken to be roughly proportional to the mean value of the east duration coefficient. Thus we see that the change occurs first at the hill stations of the Deccan and Konkan, next in the south-western part of the Deccan, then in the northern and north-eastern parts of the Deccan as far south as Sholápur, about the same time in the Konkan, afterwards in Guzerat, then in Malwa, and lastly at Kurrachee.

252. A reference to the maps (Plates LV. to LXVII.) will give a clearer view of the nature of the wind variation of Upper Sind. We observe already in May signs of an indraught* of air towards the valleys intervening between the Hala and Suleiman mountains, an indraught which has already been noticed as constituting the prevalent wind of that district during the monsoon; for whilst the prevalent wind is due west at Kurrachee, it has backed to west-south-west at Tando Aláhyar, and the reverse direction to this is weakly prevalent at Rohri. In June, whilst the arrow of Kurrachee remains nearly due west, that of Tando Aláhyar has backed further to south-south-west, that of Mehar is south-east, and that of Rohri has veered to east-south-east. In July the arrows are in the same directions, except that that of Tando Aláhyar has veered to south-west, and we have a new arrow for Tháru Sháh intermediate in direction between those of Tando Aláhyar and Mehar, viz., south by east. The gradual backing of the wind up the Indus valley is still as well marked in August as in July; but we have another new arrow for Sehwan, in the direction south-south-west, apparently less affected by the indraught than the others. In September the principal change is that the arrow of Mehar has backed to due east. October shows a radical change in the directions of the arrows, those of Jacobabad and Mehar being now from north, and that of Rohri having backed to east, whilst that of Sehwan has veered still further to west-north-west. This change is even more pronounced in the next month, November, which is the last for which we have data for the marking of the arrows. The directions of the arrows in this month are, at Jacobabad north-east, Rohri and Mehar north, and Sehwan north-north-east.

253. Of the stations for which we have relative duration coefficients for the full year, Purandhar alone has a minute east duration component, the prevalent winds of all the rest blowing to landward. For the coast—at Kurrachee, Bombay, and Goa—the excess duration of westerly winds is very considerable, but in Guzerat, on the Deccan, and at the hill stations generally, it is, though well marked, of less amount. At Mhow the prevalent wind, though still a little from westward, is principally towards the interior of the Malwa plateau, its direction being from south-south-west.

Rainfall of the Presidency.

254. Of documentary information on this subject we have at command 186 abstracts of individual registers, prepared by the Secretary and Curator of the Government Central

* This word is used only as descriptive, not as explanatory, of the phenomena.

Museum, and showing the aggregate rainfall for each month of the years 1861 to 1868, or for as many of those months and years as the records embrace; also, we have registers from the Medical Department for 13 stations, and for periods of various length, included between the years 1862 and 1872, and in one case extending backward to 1856; and in continuation of a portion of the records embodied in the abstracts first mentioned we have printed sheets of rainfall returns taken from the "Bombay Government Gazette" up to the year 1873, corrected here and there in manuscript. The latter were received from the Sanitary Commissioner, in whose hands the collection and publication of rainfall returns has been placed since the year 1872. These have served as well for the extension of the period of 161 of the original abstracts, as for the compilation of abstracts for 92 additional stations. Finally, we have the records of the Goa and Colába Observatories, and of the four provincial observatories of the Bombay Presidency. With exception as to districts not directly under British rule, the gauges are well distributed over the country, being placed generally at the various civil and military hospitals, and at the principal villages of the various collectorates, the latter being under the direction of the revenue officers of the several districts.

255. Until recently it does not appear to have been considered necessary in so simple a matter as the measurement of rainfall to inquire whether the returns correctly represented the actual rainfall at the several stations. But an extensive examination of the gauges was made in the year 1873; the diameters of the gauge and of the measuring vessel were measured, and the height of some reading (say) 1·00 inch or 0·50 inch on the measuring vessel, and with these data was calculated a factor for converting the rainfall, as read off, into true inches. The method is theoretically correct, but owing to irregularities in the figure of the glass measuring vessels, and to roughness of the means and manner of measurement, the results of the tests are often of little value; for example, a vessel about $1\frac{3}{4}$ inches in diameter was measured with a scale of eighths of an inch, a case in which the rejected excess above the greatest integral number of eighths of an inch might cause an error of 14 per cent. in the factor. Of 172 stations for which we have returns, and which reported the results of the examination of the gauges, 141 gave factors differing from unity by less than 10 per cent., and only three gave unapplied factors differing from unity by as much as 20 per cent.; and of these three, the returns for one exhibited extravagant inconsistencies, which gave sufficient reason for its rejection; for the second there was a body of eight years' records to which the factor did not apply, so that the station was fully represented without using the doubtful numbers; and the third was evidently one of a number of stations which had been inadvertently supplied with measuring vessels adapted to an 8-inch instead of a 4-inch gauge.

256. Under these circumstances, in which it seems expedient to trust that the optician's instrument is what it professes to be, rather than to correct its indications by the rough appliances available, we have adopted the following procedure. In the first place, all monthly averages derived from less than two complete months' observations were rejected; and one was rejected for each of two stations, because for eleven months of the year there were no such complete averages. Secondly, for each of the stations which had reported factors within 10 per cent. of unity, the average rainfall of each month of the year was calculated from the monthly aggregate of all the years over which the record extended,

and the sum of these monthly averages was taken to represent the average rainfall of the year. The stations having then been dotted out upon a skeleton map, the numbers representing the annual rainfall were marked against the respective stations, when it was found that there was a considerable degree of agreement amongst the members of groups of stations similarly situated. Thirdly, similar monthly and annual averages of rainfall were calculated for all the other stations, without applying any corrections to the monthly aggregates of the originally reported numbers. These stations were then dotted out upon the map, and the annual average for each station was compared with the numbers already entered in the map for the group of neighbouring stations. Allowing for probable or known singularities of station—such as extraordinary elevation above the surrounding country, or the like—the uncorrected annual averages for these stations were found to be generally in fair agreement with the others; and in one instance only—viz., one of those mentioned above as having a wrong measuring vessel—did it seem advisable to apply a correcting factor. The wrong vessels are known to have been issued in 1869, and it is from this year that the register in question dates. In the case of nine other stations, whose annual falls showed considerable discrepancies as compared with the general fall of their respective localities, whilst nothing appeared on the face of the records to justify their rejection, the least objectionable course has seemed to be to separate these stations in the tables which follow from the large number of accordant stations, and to make no use of their monthly and annual means in calculating the average rainfall of the districts in which they respectively lie. These stations do not appear, in any way, on the rainfall maps to be presently described. One register was rejected because fractions of an inch had been systematically discarded, and two on account of large inconsistencies in the recorded falls of different years.

257. The arrangement of stations in the following table is according to the drainage system to which they severally belong, the stations on the slopes to the right and left of the great river-courses being classed separately. The table shows the correcting factors which have been spoken of, for every station which reported either the requisite data or the calculated value of the factor; also the sources from which the records which have yielded the monthly and annual averages of rainfall of each station have been obtained, and the period of observation. The number entered in *italic* above each monthly average shows the number of months' observations from which the average was derived. At many stations no observations were taken until the year 1869 in other than the monsoon months, June to September; consequently, as it was impossible to determine whether the blanks in the records implied no rain or no observations, the averages of the months October to May have been determined from the records of the years following 1868; but to this rule exception has been made in the cases of the observatories of Goa, Colába, Belgaum, Poona Deesa, and Kurrachee.

TABLE 151.

258.—SHOWING the AVERAGE MONTHLY and ANNUAL FALL of RAIN at STATIONS in the BOMBAY PRESIDENCY, SIND, and RAJPOOTANA.

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.*
								PART 1.											
1		Keti Bandar	3 1·23	3 ·27	3 ·55	3 ·00	3 1·67	5 1·89	5 2·30	5 1·81	5 1·34	3 ·00	3 ·00	3 ·16	11·22	7·34	1800+ 67–71	1·20	G. S.
2		Kurrachee	22 ·86	22 ·26	23 ·40	23 ·00	23 ·11	30 ·44	31 2·53	31 2·18	30 1·32	23 ·08	23 ·05	23 ·15	8·57	6·67			C.
		Kurrachee Observatory	16 ·80	16 ·21	17 ·16	17 ·00	17 ·09	17 ·24	17 2·59	17 2·05	17 ·90	17 ·11	17 ·03	17 ·20	7·38	5·78	56–72		O.
		Kurrachee Railway Workshop	3 1·03	3 ·30	3 ·83	3 ·00	3 ·20	3 1·21	3 4·75	3 1·37	3 3·58	3 ·00	3 ·00	3 ·04	3 13·31	10·91	69–71		S.
		Kurrachee						7 ·27	8 ·84	8 3·07	7 ·09					4·27	61–68	1·15	G.
		Landi	3 1·02	3 ·50	3 1·30	3 ·00	3 ·17	3 1·17	3 4·47	3 1·42	3 4·33	3 ·00	3 ·17	3 ·00	14·55	11·39	69–71		S.
3		Dárbegi	3 ·50	3 ·19	3 ·34	3 ·00	3 ·00	3 ·83	3 6·34	3 ·38	3 2·32	3 ·00	3 ·00	3 ·00	10·90	9·87	69–71		S.
4		Tatta	2 ·07	2 ·00	2 ·00	2 ·00	2 ·00	2 ·53	2 2·76	2 ·37	2 ·41	2 ·00	2 ·00	2 ·24	4·38	4·07	72–73	1·12	S.
5		Jungsháhi	3 ·74	3 ·04	3 ·61	3 ·00	3 ·03	3 1·52	3 4·49	3 1·13	3 2·56	3 ·00	3 ·07	3 ·00	11·19	9·70	69–71		S.
6	INDUS, Right Slope.	Jerruck	2 ·00	2 ·00	2 ·00	2 ·00	2 ·00	4 ·00	4 2·01	4 1·41	4 ·83	2 ·00	2 ·00	2 ·45	4·70	4·25	67–68 & 72–73	1·12	G. S.
7		Balari	3 ·57	3 ·27	3 ·68	3 ·00	3 ·00	3 1·72	3 3·11	3 ·76	3 1·22	3 ·00	3 ·33	3 ·00	8·66	6·81	69–71		S.
8		Tháno Bula Khan	2 ·10	2 ·03	2 ·02	2 ·00	2 ·00	4 ·00	4 2·84	4 1·97	4 ·55	2 ·00	2 ·00	2 ·12	6·36	5·63	67–68 & 72–73	1	G. S.
9		Kotri	4 ·36	4 ·27	4 ·60	4 ·46	4 ·00	10 ·52	10 1·60	10 3·24	10 ·57	4 ·00	4 ·17	4 ·00	7·79	5·93	63–72	1	G. S.
10		Sehwan	2 ·48	2 ·22	2 ·35	2 ·02	2 ·00	6 ·01	6 1·47	6 3·14	6 ·97	2 ·00	2 ·00	2 ·00	6·66	5·59	65–69 & 71		G. S.
11		Mehar	4 ·38	4 ·02	4 ·98	4 ·00	4 ·04	4 ·51	4 ·21	4 3·28	4 1·53	4 ·00	4 ·00	4 ·11	7·06	5·53	69–70 & 72–73	1	G. S.
12		Lárkána	4 ·42	4 ·04	4 1·22	4 ·00	4 ·03	8 ·46	75 81 ·69	8 1·91	8 ·85	4 ·00	4 ·00	4 ·12	5·74	3·91	65–70 & 72–73		G. S.
13		Sukkur	2 ·23	2 ·00	2 ·00	2 ·00	2 ·72	2 ·00	2 2·91	2 ·06	2 ·00	2 ·01	2 ·00	2 ·20	4·13	2·97	72 & 73	1	S.
14		Shikárpur	4 ·45	4 ·04	4 1·00	4 ·02	4 ·00	10 ·17	10 ·61	10 1·44	10 ·01	4 ·00	4 ·00	4 ·00	3·74	2·23	63–72	1·11	G. S.
15		Jacobabad	3 ·65	3 ·25	3 ·43	3 ·10	3 ·19	11 ·12	11 ·95	11 1·11	10 ·23	3 ·00	3 ·00	3 ·06	4·99	2·41	61–69 & 72–73	1	G. S.
16		Mirpur Batoro	3 ·42	3 ·04	3 ·57	3 ·00	3 ·02	9 ·62	9 2·18	9 3·68	9 ·90	3 ·00	3 ·12	3 ·01	8·56	7·38	63–71	1·17	G. S.
17		Tando Mahammad Khan						9 ·04	9 ·49	9 1·64	9 ·57					2·74	61–68 & 72	1·10	G. S.
18		Hyderabad	3 ·47	3 ·30	3 ·26	3 ·05	3 ·00	9 ·86	9 1·31	9 2·57	9 ·59	3 ·02	3 ·00	3 ·0	6·43	5·33	63–71	1	G. S.
19		Tando Alábyar						2 ·46	3 1·18	3 ·56	4 ·41					2·61	67 & 68 & 72–73		G. S.
20	INDUS, Left Slope.	Hála						2 ·00	2 1·77	2 3·61	2 ·85	2 ·00	2 ·00	2 ·05		6·23	72–73		S.
21		Tháru Sháh	3 ·23	3 ·00	3 ·41	3 ·03	3 ·00	4 ·29	4 2·13	4 2·76	4 1·27	3 ·00	3 ·02	3 ·11	7·25	6·45	67, 69 72–73	1	S.
22		Rohri	4 ·37	4 ·22	4 ·65	4 ·51	4 ·62	12 ·44	12 ·33	12 1·14	12 ·36	4 ·00	4 ·00	4 ·20	4·84	2·27	61–70 & 72–73	1	G. S.
23		Khipra	2 ·52	2 ·00	2 ·00	2 ·00	2 ·00	2 1·18	2 2·85	2 ·89	2 2·78	2 ·00	2 ·00	2 ·00	8·22	7·70	69–70	1·00	S.
24		Umarkot	1 ·00	1 ·00	1 ·00	1 ·00	1 ·00	7 1·81	7 3·09	7 7·19	7 ·80	1 ·00	1 ·00	1 ·00	12·89	12·89	63–69	1·01	G. S.

* In the column headed "Sources of Records from which Averages have been derived," G. stands for Secretary and Curator, Government Central Museum S. for Sanitary Commissioner; M. for Medical Departments; O. for Observatories; and C. for results from different registers combined.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
25		Mitti	5 ·16	5 ·21	5 ·00	5 ·17	5 ·43	8 ·77	8 2·25	9 5·17	9 ·61	5 ·00	5 ·08	5 ·00	9·85	8·80	1800+ 65–73	1·00	S.
26		Nagar Parkar	4 ·20	4 ·08	4 ·00	4 ·00	4 1·23	10 2·32	10 4·07	10 7·77	10 ·66	4 ·00	4 ·02	4 ·05	16·40	14·82	63–71 & 73		G. S.
27	KUTCH.	Bhuj	4 ·01	4 ·27	4 ·16	4 ·05	4 ·00	13 2·21	13 4·35	13 4·68	13 1·81	5 ·52	5 ·00	5 ·10	14·16	13·05	61–73	1	G. S.
28		Wadhwan						2 2·03	2 3·28	2 13·30	2 4·83					23·44	67–68		G.
29		Dhandhuka	3 ·00	3 ·00	3 ·00	3 ·00	3 1·33	8 3·51	9 6·44	9 8·90	9 3·54	4 ·54	3 ·88	3 ·00	25·14	22·39	63–71		G. S.
30	KATTIWAR.	Rájkot	3 ·02	3 ·23	3 ·00	3 ·00	3 ·21	11 6·47	11 9·12	11 8·76	11 3·83	3 ·00	3 ·00	3 ·00	28·64	28·18	61–69 & 72–73	1·00	G. S.
31		Bhaunager						8 5·28	8 4·83	8 10·45	8 1·94					22·50	61–68		G.
32		Gogo	3 ·00	3 ·00	3 ·52	3 ·00	3 ·69	10 3·99	10 5·75	10 5·93	10 3·12	3 ·41	3 ·68	3 ·00	21·09	18·79	62–71	1·00	G. S.
33	WESTERN BUNNASS, Left Slope.	Deesa	16 ·19	17 ·14	17 ·14	17 ·00	17 ·10	17 2·83	16 9·28	16 9·24	16 2·55	15 1·14	15 ·13	16 ·03	25·77	23·90	56–72		O.
34		Pálanpur	2 ·00	2 ·23	2 ·00	2 ·00	2 ·00	5 1·42	5 6·47	5 15·91	5 3·28	2 ·00	2 ·00	2 ·00	27·31	27·08	66–68 72 & 73	1	S.
35	SABARAMUTI, Right Slope.	Dholka	3 ·00	3 ·00	3 ·02	3 ·00	3 1·75	9 2·58	9 9·11	9 9·69	9 2·71	3 ·09	3 ·49	3 ·00	26·44	24·09	63–71	1	G. S.
36		Sánand	3 ·00	3 ·00	3 ·11	3 ·01	3 ·42	5 2·09	5 9·21	5 11·49	5 4·73	3 ·19	3 ·52	3 ·00	28·77	27·52	67–71	1	G. S.
37		Mátar	3 ·00	3 ·01	3 ·00	3 ·00	3 ·17	8 4·48	8 11·90	8 7·64	8 5·61	3 ·14	3 ·00	3 ·00	29·95	29·63	61–63 67–71	1	G. S.
38		Kaira	3 ·00	3 ·00	3 ·00	3 ·00	3 ·02	13 4·62	13 10·31	13 10·08	13 3·17	5 ·05	5 ·52	5 ·01	28·78	28·18	61–73		G. S.
39		Nariád	3 ·00	3 ·00	3 ·06	3 ·00	3 ·56	11 4·33	11 11·67	11 10·31	11 3·55	3 ·29	3 ·17	3 ·20	31·14	29·86	61–71	1	G. S.
40	SABARAMUTI, Left Slope.	Mahudha						6 4·57	6 11·12	6 9·90	6 2·03					27·62	61–66	1	G.
41		Thásra	3 ·00	3 ·00	3 ·05	3 ·04	3 ·26	11 4·79	11 11·07	11 9·77	11 4·35	3 1·08	3 ·00	3 ·00	31·41	29·98	61–71	1	G. S.
42		Kapadwanj	3 ·00	3 ·00	3 ·00	3 ·00	3 ·00	9 5·85	11 9·74	11 10·04	11 3·87	3 1·43	3 ·00	3 ·00	30·93	29·50	61–71		G. S.
43		Ahmedabad	4 ·00	4 ·00	4 ·07	4 ·05	4 1·27	11 3·17	11 8·53	12 11·74	12 3·23	5 ·69	5 ·32	5 ·04	29·11	26·67	62–73	1	G. S.
44		Parántij	3 ·00	3 ·00	3 ·00	3 ·00	3 ·22	6 2·82	6 8·21	6 13·84	6 4·94	4 ·17	3 ·08	3 ·19	30·47	29·81	66–71		G. S.
45		Borsad	3 ·00	3 ·03	3 ·00	3 ·00	3 ·44	11 3·98	11 10·28	11 12·86	11 4·64	3 ·31	3 ·28	3 ·10	32·92	31·76	61–71	1	G. S.
46	MAHI, Right Slope.	Anand	3 ·00	3 ·03	3 ·00	3 ·00	3 ·01	5 5·86	5 11·78	5 9·07	5 5·01	3 ·08	3 ·00	3 ·02	31·86	31·72	67–71	1	G. S.
47		Virpur	2 ·00	2 ·00	2 ·00	2 ·00	2 ·00	3 6·74	3 10·50	2 5·48	3 10·34	3 ·77	3 ·00	3 ·00	33·83	33·06	69–71	1·09	S.
48		Wágra	3 ·00	3 ·00	3 ·00	3 ·00	3 ·65	10 3·95	10 7·91	10 7·78	10 4·50	3 ·82	3 ·42	3 ·18	26·21	24·14	62–71	1	G. S.
49	MAHI, Left Slope.	Amod	3 ·00	3 ·01	3 ·19	3 ·00	3 1·08	10 4·59	10 7·99	10 9·90	10 3·47	3 ·33	3 ·41	3 ·00	27·97	25·95	62–71	1	G. S.
50		Jambusar	3 ·00	3 ·00	3 ·02	3 ·17	3 ·99	10 3·48	10 9·16	10 7·96	10 5·80	3 ·37	3 ·47	3 ·00	28·42	26·40	62–71	1	G. S.
51		Baroda	4 ·00	4 ·00	4 ·00	4 ·00	4 ·16	15 5·72	16 9·91	16 12·48	16 3·95	4 ·08	4 ·20	4 ·00	32·50	32·06			C.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
		Baroda—*cont.* Residency	4 ·00	4 ·00	4 ·00	4 ·00	4 ·16	11 5·87	11 10·01	11 11·43	11 4·76	4 ·08	4 ·20	4 ·00	32·51	32·07	1800+ 62–72		G. S.
		(Rewa Kanta Agency)						4 5·31	5 9·69	5 14·81	5 2·16					31·97	64–68		G.
52		Hálol	4 ·00	4 ·06	4 ·00	4 ·00	4 ·05	8 4·39	8 13·55	6 13·96	8 4·83	5 ·71	5 ·08	5 ·00	37·63	36·73	66–73	1	G. S.
53		Kálol	4 ·00	4 ·00	4 ·00	4 ·00	4 ·00	8 4·51	8 13·77	8 12·39	8 4·70	5 ·36	5 ·11	5 ·00	35·84	35·37	66–73	1	G. S.
54	MAHI, Left Slope —*cont.*	Godra	5 ·00	5 ·12	5 ·00	5 ·02	5 ·06	8 5·85	8 14·29	8 14·62	8 6·21	5 1·12	5 ·13	5 ·05	42·47	40·97	66–73	1	G. S.
55		Ságtála	3 ·00	3 ·01	3 ·00	3 ·00	3 ·01	3 2·43	8 14·05	8 6·91	8 9·37	3 1·10	3 ·00	3 ·00	33·88	32·76	69–71	1·06	S.
56		Báriya	5 ·00	5 ·60	5 ·02	5 ·00	5 ·13	6 6·47	6 14·52	6 12·14	6 7·49	5 ·84	5 ·22	5 ·15	42·58	40·62	68–75	0·95	S.
57		Dohad	5 ·02	5 ·07	5 ·02	5 ·10	5 ·07	13 5·32	13 10·12	13 7·75	13 3·65	5 ·53	5 ·80	5 ·09	28·54	26·84	61–73	1	G. S.
58		Jhálod	4 ·03	4 ·40	4 ·05	4 ·00	4 ·03	8 3·21	8 11·24	8 9·89	8 3·11	5 ·59	5 ·13	5 ·02	28·70	27·45	66–73	1	G. S.
59		Lunáwára	5 ·00	5 ·10	5 ·00	5 ·00	5 ·42	5 5·42	5 12·81	5 11·71	5 6·69	5 ·83	5 ·10	5 ·00	38·08	36·63	69–73	2·83*	S.
60	NURBUDDA, Right Slope.	Broach	5 ·00	5 ·01	5 ·00	5 ·00	5 ·00	13 6·09	13 10·71	13 8·63	13 4·91	5 ·81	5 ·50	5 ·08	31·74	30·34	61–73	1·00	G. S.
61		Sánkhera	2 ·00	2 ·00	2 ·00	2 ·33	2 ·00	2 6·17	3 13·95	2 3·94	2 4·34	2 ·26	2 1·01	2 ·00	30·00	28·40	69–72		S.
62	NURBUDDA, Left Slope.	Hánsot	3 ·00	3 ·00	3 ·01	3 ·00	3 ·00	7 3·81	7 8·26	7 12·65	7 3·21	3 ·75	3 ·43	3 ·00	29·12	27·93	65–71	1	G. S.
63		Ankleswar	3 ·00	3 ·00	3 ·00	3 ·00	3 ·00	9 5·43	9 10·85	9 10·80	9 4·37	5 ·80	3 ·53	3 ·03	32·81	31·45	63–71	1	S.
64		Ránder						3 9·34	2 14·12	3 9·22	4 9·82	4 1·15	4 ·00			42·50	67–70		M.
65		Olpád	3 ·00	3 ·00	3 ·00	3 ·00	3 ·76	9 6·25	10 9·44	10 8·27	10 4·74	3 ·11	3 1·27	3 ·10	30·94	28·70	62–71	1·00	S.
66		Mándvi	5 ·00	5 ·00	5 ·00	5 ·00	5 ·00	11 8·08	11 17·57	12 12·69	12 6·22	7 1·26	5 ·67	5 ·02	46·51	44·56	62–73	1·00	S.
67		Taloda	3 ·00	3 ·00	3 ·00	3 ·00	3 ·00	4 4·06	4 9·16	4 7·67	4 4·20	3 1·19	3 ·30	3 ·00	26·58	25·09	68–71	1	G. S.
68		Sháháda	3 ·00	3 ·00	3 ·00	3 ·00	3 ·01	4 2·99	4 6·12	4 4·78	4 3·69	3 ·21	3 ·20	3 ·15	20·15	17·58	68–71	1	S.
69	TAPTI, Right Slope.	Sultanpur						8 4·11	8 6·26	8 8·79	8 2·35					21·51	61–68	1	G.
70		Shirpur	3 ·00	3 ·00	3 ·00	3 ·00	3 1·73	4 4·25	4 5·09	4 6·80	4 3·69	3 2·13	3 2·54	3 ·00	26·23	19·83	68–71	1	S
71		Thálner						8 4·44	8 6·63	8 6·04	8 2·22					19·33	61–68	1	G.
72		Chopra	3 ·08	3 ·00	3 ·00	3 ·00	3 ·17	11 3·35	11 6·38	11 6·46	11 2·39	3 2·66	3 ·75	3 ·00	22·24	18·58	61–71	1	G. S.
73		Sauda	3 1·90	3 ·00	3 ·05	3 ·00	3 ·00	11 5·13	11 6·55	11 5·28	11 3·88	3 1·89	3 ·59	3 ·00	25·27	20·84	61–71	1	G. S.
74		Ráver						7 5·38	7 5·99	7 7·69	7 4·68				2	23·74	61–67	1	G.

* Factor applied by observer.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
75		Surat	4 .00	4 .00	4 .00	4 .00	3 .00	10 9·99	10 12·27	11 10·86	11 6·46	5 .59	5 .29	5 .08	40·54	39·58	1800+ 63–73	1·16	S.
76		Bardoli	3 .00	3 .15	3 .00	3 .00	3 .68	9 8·64	10 17·98	10 14·11	10 6·09	3 1·65	3 .76	3 .27	50·33	46·82	62–71	1·00	S.
77		Wálod	3 .00	3 .05	3 .00	3 .00	3 .67	7 7·11	7 18·43	7 16·74	7 5·22	5 3·10	3 1·01	3 .06	52·39	47·50	65–71		S.
78		Nandurbár	3 .00	3 .00	3 .00	3 .00	3 .00	11 4·36	11 6·54	11 7·36	11 2·59	3 1·85	3 .18	3 .00	22·88	20·85	61–71	1	G. S.
79		Virdel	3 .00	3 .00	3 .00	3 .00	3 .50	11 4·36	11 4·17	11 4·92	11 2·80	3 2·91	3 .96	3 .00	20·62	16·25	61–71	1	G. S.
80		Amalner	3 .79	3 .00	3 .01	3 .00	3 .18	11 4·58	11 7·62	11 5·83	11 4·71	3 2·67	3 1·13	3 .00	27·52	22·74	61–71	1	G. S.
81		Dhulia	3 .87	3 .03	3 .01	3 .04	7 .38	18 3·89	18 3·59	18 3·33	17 3·66	14 1·95	8 1·10	7 .19	19·04	14·47			C.
		Civil Hospital	5 .67	5 .05	5 .02	5 .07	5 .57	7 3·91	7 4·11	7 3·06	7 4·55	7 1·71	5 1·26	5 .26	20·24	15·63	67–73	1·20	S.
		Mámledár's Kutcherry	3 1·20	3 .00	3 .00	3 .00	2 .20	11 3·88	11 3·27	11 3·49	10 3·05	7 2·19	3 .83	2 .00	18·11	13·69	61–71		G. S.
82		Erandol	3 1·34	3 .00	3 .00	3 .00	3 .12	11 5·35	11 5·92	11 6·93	11 3·81	3 2·14	3 .88	3 .00	26·49	22·01	61–71	1	G. S.
83		Násirabad	3 .00	3 .00	3 .00	3 .00	3 .41	11 4·36	11 7·97	11 5·87	11 4·69	3 2·04	3 .12	3 .00	25·46	22·89	61–71	1	G. S.
84	TAPTI, Left Slope.	Bhusáwal	3 1·35	3 .00	3 .00	3 .00	3 .00	4 4·24	4 5·80	4 4·37	4 4·31	3 1·64	3 .40	3 .00	22·11	18·72	68–71	1	S.
85		Warangaon						7 4·37	7 7·60	7 6·30	7 4·05					22·32	62–68	1	G.
86		Jámner	3 1·98	3 .00	3 .04	3 .00	3 .14	11 4·32	11 6·69	11 5·99	11 4·52	3 2·56	3 .51	3 .00	26·75	21·52	61–71	1	G. S.
87		Lohára						8 5·53	8 9·14	8 8·59	8 4·96					28·22	61–68	1	G.
88		Páchora	3 2·79	3 .00	3 .00	3 .00	3 .00	4 6·29	4 6·30	4 3·66	4 9·22	3 2·07	3 .62	3 .00	30·95	25·47	68–71	1	S.
89		Bhadgaon						7 4·09	7 6·73	7 7·19	7 4·47					22·48	61–67	1	G.
90		Chálisgaon	3 1·58	3 .00	3 .00	3 .00	3 .42	11 5·24	11 5·65	11 4·83	11 6·48	3 3·80	3 .72	3 .00	28·72	22·20	61–71	1	G. S.
91		Nándgaon	3 .92	3 .00	3 .00	3 .00	3 .79	4 3·88	4 4·12	4 3·22	4 6·98	3 3·19	3 1·88	3 .00	24·98	18·20	68–71		G. S.
92		Málegaon	3 .67	3 .00	3 .00	3 .00	3 .50	11 4·64	11 2·92	11 3·77	11 5·77	3 2·58	3 1·31	3 .00	22·16	17·10	61–71	·86	G. S.
93		Chándor	3 2·14	3 .00	3 .00	3 .00	3 .89	11 5·27	11 4·77	11 5·26	11 4·63	3 5·43	3 1·86	3 .79	31·04	19·93	61–71		G. S.
94		Abhona	2 .00	2 .00	2 .00	2 .00	2 .00	2 16·75	2 6·49	2 4·02	2 3·94	2 4·19	2 1·01	2 .00	36·40	31·20	70–71	2·56*	S.
95		Pimpalnar	3 .33	3 .00	3 .00	3 .00	3 .00	11 3·61	11 5·85	11 6·04	11 2·61	3 2·38	3 .30	3 .00	21·12	18·11	61–71	1	G. S.
96		Jalálpur	3 .00	3 .00	3 .00	3 .00	3 .00	9 8·53	9 16·13	10 13·07	10 6·19	3 1·91	3 .33	3 .30	46·46	43·92	62–71		S.
97		Chikhli	3 .00	3 .00	3 .00	3 .00	3 .83	9 13·15	9 25·59	10 19·56	10 8·14	3 2·18	3 .20	3 .12	69·77	66·44	62–71		S.
98	KONKAN, Coast Side.	Bulsar	3 .00	3 .00	3 .10	3 .00	3 1·14	9 13·60	9 20·49	10 16·47	10 10·06	3 2·61	3 .00	3 .04	64·51	60·62	62–71	1·06	S.
99		Párdi	3 .03	3 .00	3 .06	3 .00	3 .79	9 12·86	9 24·17	10 17·74	10 10·30	3 2·77	3 .44	3 .23	69·39	65·07	62–71	1·00	S.
100		Dáhánu	3 .05	3 .00	3 .00	3 .00	3 .76	10 14·67	10 21·63	10 15·62	10 7·54	3 2·62	3 .49	3 .04	63·42	59·46	62–71	1·13	G. S.
101		Máhim	3 .37	3 .00	3 .00	3 .00	3 .25	10 16·54	10 21·98	10 16·80	10 7·47	3 3·43	3 .57	3 .00	67·41	62·79	62–71	·97	G. S.

* Factor applied.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
102		Bassein	3 ·30	3 ·00	3 ·00	3 ·00	3 ·47	10 15·36	10 21·19	10 15·03	10 8·22	3 1·69	3 ·54	3 ·12	62·92	59·80	1800+ 62–71	1·01	G. S.
103		Bhiwandi	3 ·69	3 ·00	3 ·00	3 ·00	3 ·51	5 16·40	5 34·82	5 17·97	6 11·17	3 3·74	3 ·70	3 ·00	86·00	80·36	66–71		G. S.
104		Kalyán	3 ·67	3 ·00	3 ·00	3 ·00	3 1·03	6 15·13	6 30·04	6 20·91	6 9·13	3 3·90	3 ·07	3 ·10	80·98	75·21	66–71	1·12	G. S.
105		Tanna	4 ·00	4 ·00	4 ·00	4 ·00	4 ·00	12 23·47	12 29·57	11 24·54	11 9·92	4 3·17	4 ·00	4 ·00	90·67	87·50	62–73	·97	G. S.
106		Coorla	6 ·18	7 ·00	7 ·00	7 ·00	6 ·55	7 19·42	5 29·96	6 16·15	7 10·57	7 2·17	7 ·46	8 ·00	79·47	76·11	65–72		M.
107		Bandora						8 18·88	7 23·26	8 17·67	8 8·53	8 1·22	8 ·35		68·34	64·72	64–72	1·08	M.
108		Panwel	3 ·60	3 ·00	3 ·00	3 ·07	3 ·72	10 22·27	10 36·64	10 26·97	8 17/30 10·99	3 5·63	3 ·59	3 ·00	104·48	96·87	62–71		G. S.
109		Uran	2 1·00	2 ·00	2 ·00	2 ·00	2 1·62	4 15·53	4 29·83	4 16·30	4 10·60	2 3·13	2 ·75	2 ·00	78·76	72·26	67–68 70–71		G. S.
110		Bombay	44 ·28	44 ·01	44 ·00	44 ·03	44 ·49	66 20·76	66 24·57	66 16·04	67 10·44	48 1·86	46 ·40	46 ·03	74·91	71·81			C.
		Colába Observatory	28 ·12	28 ·01	28 ·00	28 ·04	28 ·53	28 20·45	28 24·12	28 12·83	28 9·65	28 2·02	28 ·49	28 ·05	70·31	67·05	47–74		O.
		Town Hall	2 1·23	2 ·00	2 ·02	2 ·08	2 1·41	2 18·52	2 21·06	2 9·09	3 12·32	3 2·16	3 ·77	3 ·01	66·67	60·99	69–71		S.
		Esplanade	5 ·45	5 ·00	5 ·00	5 ·00	5 ·36	12 20·39	12 24·73	12 18·41	12 10·95	5 1·35	5 ·00	5 ·00	76·64	74·48	62–73	1	G. S.
		Jamsetjee Jeejeebhoy Hospital	4 ·52	4 ·00	4 ·00	4 ·00	4 ·24	12 21·72	12 25·65	12 19·89	12 11·10	7 1·78	5 ·00	5 ·00	80·90	78·36	62–73	1	S.
		European General Hospital	5 ·44	5 ·00	5 ·00	5 ·00	5 ·25	12 21·25	12 24·97	12 18·47	12 10·66	5 1·38	5 ·48	5 ·00	77·90	75·35	62–73	1·00	G. S.
111	KONKAN, Coast Side—*cont.*	Pen	3 1·33	3 ·00	3 ·00	3 ·10	3 ·00	10 20·95	10 32·18	10 21·81	10 9·67	3 3·63	3 ·23	3 ·00	89·90	84·61	62–71		G. S.
112		Alibág	3 ·70	3 ·00	3 ·00	3 ·00	3 ·66	10 17·50	10 22·40	10 15·00	10 10·89	3 2·76	3 ·43	3 ·00	70·34	65·79	62–71	·99	G. S.
113		Roha	3 1·83	3 ·00	3 ·00	3 ·62	3 ·67	10 24·79	10 37·29	10 26·27	10 13·34	5 5·37	3 ·33	3 ·00	110·51	101·69	62–71	1	G. S.
114		Mandangarh	3 2·59	3 ·00	3 ·00	3 ·12	3 1·42	10 32·71	10 46·50	10 30·38	10 14·57	8 6·05	3 ·56	3 ·00	134·90	124·16	64–71		G. S.
115		Dápoli	7 2·12	7 ·00	7 ·00	7 ·01	7 1·00	23 29·93	23 36·78	23 27·18	23 12·97	10 3·22	8 ·30	8 ·01	113·61	106·86			C.
		Civil Hospital	4 1·78	4 ·00	4 ·00	4 ·09	4 ·94	13 29·39	13 36·84	13 27·34	13 12·93	5 2·14	5 ·24	5 ·02	111·71	106·50	61–73	1	G. S.
		Mámledár's Kutcherry	3 2·57	3 ·00	3 ·00	3 ·12	3 1·07	10 30·64	10 36·71	10 26·97	10 13·02	3 4·29	3 ·42	3 ·00	115·81	107·34	62–71		S.
116		Khed	3 2·25	3 ·00	3 ·00	3 ·00	2 ·25	9 31·23	9 40·14	9 27·80	9 10·99	3 6·20	3 ·20	3 ·00	119·06	110·16	63–71		G. S.
117		Guhágar	3 2·92	3 ·00	3 ·00	3 ·00	3 ·82	11 20·45	11 26·76	11 17·58	11 9·88	3 2·59	3 ·53	3 ·12	75·65	68·67	61–71		G. S.
118		Malgund						6 34·54	6 31·18	6 20·39	6 9·74				95·85	62–67			S.
119		Ratnágiri	5 3·15	5 ·02	5 ·00	5 ·01	5 ·74	13 28·82	13 30·97	13 20·61	13 12·36	5 2·11	5 ·17	5 ·13	99·09	92·76	61–73	·91	G. S.
120		Lanja	3 1·56	3 ·00	3 ·00	3 ·53	3 ·98	6 32·44	6 42·95	6 25·81	6 16·99	3 4·46	3 ·51	3 ·46	126·69	118·19	66–71		G. S.
121		Rájápur	3 1·08	3 ·00	3 ·00	3 ·21	3 1·07	10 33·77	10 38·97	10 27·70	10 12·61	3 4·82	3 ·83	3 ·00	121·06	113·05	62–71	102	G. S.
122		Wagotun					2 ·05	7 31·63	7 32·74	7 22·35	7 9·87	2 2·47			96·59	62–68			S.
123		Vingorla	4 ·00	4 ·00	4 ·00	4 ·03	4 1·32	12 36·44	12 36·16	12 23·13	12 11·10	5 3·64	5 ·50	5 ·00	112·32	106·83	62–73	1	G. S.
124		Goa	11 ·24	11 ·00	11 ·06	11 ·11	12 ·92	12 33·70	12 33·16	12 19·56	12 8·82	12 4·33	12 ·97	11 ·04	101·91	95·24	60–67 70–73	1	O.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
125		Peint						8 14·12	8 35·84	8 36·76	8 9·32					96·04	1800+ 61-68		G. S.
126		Mokhára	8 ·27	8 ·00	8 ·00	8 ·00	8 ·05	10 16·79	10 32·10	10 26·78	10 11·24	8 6·65	8 ·83	8 ·18	94·89	86·91	62-71		G. S.
127		Wara	8 ·31	8 ·01	8 ·00	8 ·00	8 ·31	5 17·32	5 36·88	5 20·32	5 8·07	8 2·47	8 ·00	8 ·00	85·69	82·59	67-71		G. S.
128		Sháhápur	8 ·65	8 ·00	8 ·00	8 ·94	8 3·48	10 21·50	10 38·44	10 27·25	10 13·94	8 2·91	8 ·00	8 ·00	109·11	101·13	62-71	1·02	G. S.
129		Murbad	8 ·67	8 ·00	8 ·00	8 ·37	8 ·18	10 14·95	10 28·75	10 24·54	10 8·97	8 6·12	8 1·53	8 ·28	86·36	77·21	62-71		G. S.
130		Dahiwali						5 20·62	5 39·03	4 37·92	4 12·75					110·32	62-66		G.
131		Karjat	8 ·00	8 ·00	8 ·00	8 ·00	8 1·60	5 21·47	5 38·42	6 31·64	6 10·19	8 6·52	8 ·63	8 ·00	110·47	101·72	66-71		S.
132	KONKAN, Ghaut Side.	Khálapur	8 1·51	8 ·00	8 ·00	8 ·00	8 ·07	4 24·35	4 39·67	4 24·20	4 14·54	4 5·14	8 ·82	8 ·31	110·61	102·76	68-71		G. S.
133		Mangaon	8 2·44	8 ·00	8 ·00	8 ·02	8 ·33	5 21·69	5 36·13	5 23·17	5 18·76	8 4·22	8 ·34	8 ·00	107·10	99·75	67-71	1	G. S.
134		Mahád	8 ·00	8 ·00	8 ·00	8 ·00	8 1·15	5 28·86	5 39·87	6 30·89	6 14·90	5 5·27	8 ·25	8 ·00	121·19	114·52	66-71	1	S.
135		Chiplun	8 2·45	8 ·00	8 ·00	8 ·00	8 1·56	7 33·60	7 41·71	7 31·14	7 13·45	8 8·17	8 1·46	8 ·00	133·54	119·90	65-71		G. S.
136		Sawarde						6 34·10	6 46·19	6 34·73	6 14·98					130·00	62-67		S.
137		Sangameshwar	8 1·50	8 ·00	8 ·00	8 ·00	8 ·44	7 32·96	7 47·28	7 34·32	7 12·88	8 7·28	8 ·83	8 ·38	137·87	127·44	65-71		G. S.
138		Kharepatan	8 ·95	8 ·00	8 ·00	8 ·68	8 ·50	11 33·93	11 41·92	11 28·99	11 12·70	8 6·93	8 ·78	8 ·65	128·03	117·54	61-71		G. S.
139		Kankali						7 31·03	7 41·66	7 26·70	7 10·21					109·60	62-68		G.
140		Sáwant Wári	5 ·43	4 ·07	4 ·00	4 ·05	4 ·97	13 38·13	13 48·15	13 30·43	13 11·62	5 7·48	5 1·22	5 ·00	138·55	128·33	61-73	·99	G. S.
141		Coompta	8 1·00	8 ·00	8 ·01	8 1·27	8 4·02	9 39·83	9 47·86	9 23·45	9 9·86	8 7·36	8 ·67	8 ·06	135·39	121·00	63-71	1	G. S.
142		Honáwar	8 1·38	8 ·87	8 ·00	8 ·27	8 4·76	7 26/30 43·33	8 44·24	8 29·35	8 18·53	8 7·59	8 1·52	8 ·17	152·01	135·45	61-63 67-71		G. S.
143		Hángal	8 ·63	8 ·00	8 ·48	8 ·33	8 1·59	10 5·95	10 9·30	10 5·07	10 2·26	6 4·74	4 ·63	8 ·71	31·69	22·58	62-71	1·02	S.
144		Yellápur	8 ·04	8 ·00	8 ·00	8 1·60	8 2·06	11 19·73	11 28·89	11 20·04	11 5·28	8 6·78	8 ·81	8 ·30	85·53	73·94	61-71		G. S.
145		Supa						6 19·15	8 40·88	8 30·81	8 7·63					98·47	61-68		G.
146	NORTH CANARA.	Haliyál	8 ·51	8 ·00	8 ·13	8 ·94	8 2·64	11 12·11	11 17·69	11 15·35	11 4·03	8 8·07	8 1·70	8 ·76	63·93	49·18	61-71		G. S.
147		Bidi	1 ·00	1 ·00	1 ·00	1 ·23	8 3·09	8 11·58	8 13·04	8 8·91	8 2·14	8 4·72	2 1·24	1 ·82	45·77	35·67	62-69	1	S.
148		Dharwar	5 ·38	5 ·05	5 ·07	5 1·53	6 3·66	11 6·45	11 4·93	11 4·10	11 2·73	7 7·19	6 ·81	5 1·26	5 33·16	18·21	62-65 67-73	·90	S.
149		Dewar Hubli	8 ·55	8 ·00	8 ·00	8 ·58	8 1·50	10 5·25	10 6·85	10 5·60	10 2·51	6 6·47	4 ·87	8 ·52	30·70	20·21	62-71	106	S.
150		Misrekot	8 ·28	8 ·00	8 ·00	8 ·35	8 1·93	10 5·39	10 6·40	10 4·33	10 2·82	5 5·97	8 ·93	8 1·02	29·42	18·94	62-71		S.
151		Hubli	8 ·23	8 ·15	8 ·00	8 1·35	8 4·14	10 4·16	10 3·74	10 9 1/31 3·23	9 2·38	5 5·98	4 ·71	8 ·15	26·22	13·51	62-71	1·17	S.
152		Násirabad	8 ·51	0 ·00	2 ·28	2 ·08	8 ·23	7 3·45	6 7·65	6 4·69	7 3·89	6 ·25	8 ·01	2 ·00	21·04	19·68	62-72		M.
153	MALWA PLATEAU.	Nimach	6 ·08	6 ·26	6 ·29	6 ·09	9 ·44	10 5·09	9 10·63	10 9·01	11 5·52	11 ·49	11 ·06	5 ·01	31·97	30·25	62-72		M.
154		Mhow	4 ·12	8 ·26	8 ·29	8 ·12	8 ·32	8 5·69	4 8·38	4 7·56	5 7·11	4 1·18	4 ·28	2 ·00	31·31	28·74	62-70		M.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
155	GODAVARI, Left Slope.	Sawargaon	3 1·20	3 ·00	3 ·00	3 ·00	3 1·75	11 4·92	11 2·99	11 4·25	11 3·78	3 4·32	3 1·56	3 ·45	25·22	15·94	1800+ 61–71		G. S.
156		Yeola						5 4·34	5 3·46	5 4·18	5 3·91					15·89	62–66		S.
157		Vinchur	3 1·21	3 ·00	3 ·02	3 ·37	3 ·46	11 3·81	11 3·62	11 4·45	11 2·50	3 3·51	3 ·58	3 ·00	20·53	14·38	61–71		G. S.
158	GODAVARI, Right Slope.	Sheogaon	3 1·84	3 ·00	3 ·00	3 ·00	3 ·50	11 3·79	11 3·92	11 5·23	11 5·88	3 5·61	3 ·90	3 ·00	27·67	18·82	61–71	1·17	G. S.
159		Newása	3 1·51	3 ·00	3 ·00	3 ·00	3 ·53	11 3·34	11 2·65	11 3·28	11 4·38	3 2·76	3 ·84	3 ·00	19·29	13·65	61–71		G. S.
160		Ráhuri	3 2·30	3 ·00	3 ·00	3 ·00	3 1·23	11 4·63	11 2·23	11 3·48	11 6·00	3 4·66	3 ·78	3 ·29	25·60	16·34	61–71		G. S.
161		Kopargaon	3 1·48	3 ·00	3 ·02	3 ·04	3 ·24	10 4·61	10 2·44	11 3·71	11 3·85	3 6·57	3 1·29	3 ·21	24·46	14·61	61–71		G. S.
162		Akola	3 1·59	3 ·00	3 ·00	3 ·10	3 ·81	11 4·99	11 5·82	11 4·59	11 3·13	3 4·10	3 1·36	3 ·00	26·49	18·53	61–71	·89	G. S.
163		Sangamner	3 1·83	3 ·00	3 ·00	3 ·00	3 ·33	3 4·25	11 2·24	11 3·07	11 3·16	11 3·60	3 ·64	3 ·00	19·12	12·72	61–71		G. S.
164		Sinnar	3 ·92	3 ·00	3 ·00	3 ·01	3 ·85	11 4·28	11 3·52	11 4·63	11 3·03	3 4·31	3 ·80	3 ·31	22·66	15·46	61–71		G. S.
165		Niphád	3 ·98	3 ·00	3 ·00	3 ·00	3 ·93	10 3·97	10 3·04	11 3·95	10 2·70	3 2·63	3 ·19	3 ·16	18·55	13·66	61–71		G. S.
166		Dindori	3 ·48	3 ·00	3 ·00	3 ·03	3 1·33	11 5·13	11 6·99	11 7·02	11 3·55	3 3·77	3 ·50	3 ·32	29·12	22·69	61–71		G. S.
167		Násik	3 ·38	3 ·00	3 ·01	3 ·27	3 ·47	11 4·83	11 6·15	11 5·77	11 3·53	3 5·72	3 ·23	3 ·33	27·69	20·28	61–71	1	G. S.
168		Kávnai						6 26·33	6 43·03	6 42·77	6 14·98					127·11	61–66		G.
169		Igatpúri	3 ·41	3 ·00	3 ·00	3 ·12	3 2·38	5 16·61	5 36·56	5 28·26	5 11·83	3 5·82	3 1·17	3 ·51	103·67	93·26	67–71		S.
170	BHIMA, Left Slope.	Sholápur	2 ·00	2 ·00	2 ·00	2 ·00	2 ·59	11 3·91	11 4·52	11 5·33	11 6·13	3 5·78	3 ·37	3 ·00	26·63	19·89	61–71	1·09	G. S.
171		Mandrup						5 3·30	5 3·38	4 3/11 4·67	4 5·13					16·48	62–66		S.
172		Mohol						5 2·19	5 3·00	4 3/11 4·84	4 4·19					14·22	62–66		S.
173		Charchan						5 2·64	5 1·85	4 8/11 3·76	4 5·94					14·19	62–66	1	S.
174		Mádha	3 ·00	3 ·00	3 ·00	3 ·00	3 ·65	10 4·08	10 3·51	10 4·65	10 5·24	3 2·42	3 1·11	3 ·00	21·66	17·48	62–71	1·00	G. S.
175		Karmála	3 ·00	3 ·00	3 ·00	3 ·00	3 2·34	10 3·24	10 2·01	10 3·31	10 4·93	3 2·25	3 ·90	3 ·00	18·98	13·49	62–71	1·00	G. S.
176		Karjat	3 1·67	3 ·00	3 ·00	3 1·67	3 0·43	10 3·56	10 2·11	10 4·02	10 5·87	3 5·25	3 1·60	3 ·14	26·32	15·56	61–66 68–71		G. S.
177		Jámkhed	3 2·33	3 ·00	3 ·17	3 ·40	3 ·98	11 5·73	11 3·88	11 5·54	11 7·22	3 4·91	3 1·26	3 ·35	32·77	22·37	61–71		G. S.
178		Shrigonda	3 2·66	3 ·00	3 ·08	3 ·00	3 ·45	5 4·65	5 1·97	5 4·16	5 4·12	3 3·98	3 1·23	3 ·30	23·60	14·90	67–71	1·05	G. S.
179		Ahmednagar	5 1·75	5 ·09	5 ·05	5 ·45	5 ·69	13 5·42	13 3·17	13 4·86	13 6·44	5 4·42	5 1·20	5 ·10	28·55	19·89	61–73	1·15	G. S.
180		Párner	3 1·78	3 ·00	3 ·00	3 ·22	3 ·44	11 4·72	11 2·60	11 4·67	11 5·09	3 4·41	3 1·34	3 ·39	25·66	17·08	61–71	·89	G. S.
181		Brahmunwara						5 4·47	5 4·49	5 7·16	5 2·79					18·91	62–66		G.
182		Junnar	3 1·72	3 ·00	3 ·00	3 ·00	3 ·48	5 5·33	5 6·56	5 5·46	5 1·88	3 4·67	3 ·72	3 ·00	26·82	19·23	67–71	0·90	G. S.
183		Sirur	3 2·41	3 ·00	3 ·02	3 ·00	3 ·40	10 3·03	10 1·75	10 2·81	10 4·25	3 3·75	3 ·68	3 ·22	19·32	11·84	62–71	1·07	G. S.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
184		Pábal						5 4·36	5 2·55	5 3·93	5 2·96					13·80	1800+ 62–66		G.
185	BHIMA, Left Slope —*cont.*	Ambegaon	3 1·33	3 ·00	3 ·00	3 ·00	3 ·16	10 4·67	10 4·81	10 5·70	10 1·67	3 3·88	3 1·58	3 ·45	24·25	16·85	62–71		G. S.
186		Khed	3 1·63	3 ·00	3 ·00	3 ·00	3 1·45	10 5·20	10 4·42	10 4·69	10 2·37	3 4·48	3 1·92	3 ·25	26·41	16·68	62–71	·97	G. S.
187		Almel						5 3·10	5 2·85	4 3/31 5·16	4 5·58					16·69	62–66	1	S.
188		Sindgi	3 ·00	3 ·09	3 ·10	3 ·01	3 ·76	8 3·53	8 2·75	8 4·97	8 5·39	3 3·34	3 ·20	3 ·47	21·52	16·64	64–71	1	G. S.
189		Hippargi						6 3·56	6 2·36	5 3/31 3·42	5 8·42					17·76	62–67	1	S.
190		Indi	3 ·30	3 ·00	3 ·03	3 ·25	3 1·58	10 4·41	10 2·06	10 4·86	10 6·82	3 4·08	3 ·15	3 2·22	26·76	18·15	62–71	1	G. S.
191		Sángola	3 ·00	3 ·00	3 ·00	3 ·12	3 1·63	10 3·65	10 1·74	10 3·23	10 5·47	3 7·10	3 ·47	3 ·00	23·41	14·09	62–71	1·18	G. S.
192		Pandharpur	3 ·00	3 ·00	3 ·00	3 ·00	3 ·71	10 3·84	10 1·95	10 3·30	10 6·07	3 4·40	3 ·55	3 ·00	20·82	15·16	62–71	1·12	G. S.
193		Málsiras	3 1·63	3 ·00	3 ·08	3 ·26	3 1·45	10 2·66	10 1·42	10 3·23	10 4·61	3 4·39	3 ·76	3 ·50	20·99	11·92	62–71		G. S.
194		Indápur	3 1·95	3 ·00	3 ·25	3 ·13	3 ·18	10 3·40	10 1·55	10 2·00	10 2·47	3 2·97	3 1·86	3 ·53	17·29	9·42	62–71	1·01	G. S.
195		Bárámati	3 1·67	3 ·00	3 ·00	3 ·20	3 ·66	5 3·61	5 1·03	5 3·73	5 4·69	3 4·64	3 ·37	3 ·15	20·75	13·06	67–71	1·01	G. S.
196		Pátas	3 3·14	3 ·00	3 ·00	3 ·00	3 1·05	10 4·07	10 1·23	10 2·97	10 4·17	3 2·62	3 ·45	3 ·07	19·77	12·44	62–71	1·01	G. S.
197	BHIMA, Right Slope.	Poona	24 ·32	24 ·09	24 ·26	22 ·53	27 1·76	41 5·76	43 5·25	44 4·73	45 4·32	30 4·90	30 ·57	28 ·30	28·79	20·06			C.
		Observatory	17 ·43	17 ·06	17 ·31	17 ·56	17 1·56	16 6·19	17 6·89	17 5·09	17 4·65	17 5·54	17 ·52	17 ·29	32·09	22·82	56–72		O.
		Civil Hospital						8 5·25	8 4·65	8 5·36	8 3·62					18·88	61–68		G.
		Sassoon Hospital	3 ·00	3 ·13	3 ·02	3 ·40	3 2·46	11 5·18	12 4·28	12 4·43	12 4·82	5 3·24	5 ·63	5 ·47	26·06	18·71	62–73	·91	G. S.
		Yeroda					4 3·25	3 5·77	3 4·56	4 4·48	5 3·96	5 4·92	5 ·79	3 ·37		18·77	67–71	1·01	M.
		Kirkee	4 ·07	4 ·21	4 ·26	2 ·50	3 ·18	3 6·88	3 2·12	3 2·54	3 2·98	3 4·03	3 ·36	3 ·00	20·13	14·52	62–65	1	M.
198		Kharkála	3 1·80	3 ·00	3 ·00	3 ·23	3 ·45	10 12·94	10 24·22	10 19·97	10 4·64	3 3·38	3 ·30	3 ·00	67·93	61·77	62–71	1·01	G S.
199		Dahiwali	3 2·39	3 ·00	3 ·04	3 ·00	3 2·27	10 3·96	10 1·57	10 2·68	10 3·67	3 4·53	3 2·03	3 ·28	23·42	11·88	62–71		G. S.
200		Khandála	3 1·50	3 ·00	3 ·00	3 ·00	3 ·66	10 3·73	10 2·01	10 2·89	10 2·28	4 4·58	3 5·78	3 ·18	23·61	10·91	62–71		S.
201		Moolsi	3 1·67	3 ·00	3 ·00	3 ·05	3 ·48	10 10·47	10 17·70	10 12·59	10 3·66	3 5·18	3 ·36	3 ·05	52·21	44·42	62–71		G. S.
202		Muddebihál	3 ·00	3 ·00	3 ·00	3 ·20	3 1·06	10 2·79	10 2·01	10 4·55	10 4·06	3 5·03	3 ·33	3 ·00	20·03	13·41	62–71	1	G. S.
203		Bágewári	3 ·17	3 ·00	3 ·00	3 ·00	3 ·18	7 2·47	7 3·70	7 4·33	7 3·45	3 3·76	3 1·31	3 ·00	19·37	13·95	65–71	1	G. S.
204	KRISHNA, Left Slope.	Managoli						6 4·03	6 2·69	6 4·28	5 5·18					16·18	62–67	1	S.
205		Bijápur	3 ·08	3 ·00	3 ·41	3 ·11	3 ·68	10 4·07	10 1·84	10 4·46	10 4·72	3 3·40	3 ·38	3 1·42	21·57	15·09	62–71	1	G. S.
206		Athni	3 ·73	3 ·00	3 ·02	3 ·15	5 ·64	10 3·40	10 1·18	10 2·76	10 3·03	3 4·02	3 ·06	3 1·33	17·32	10·37	62–71	1	S.
207		Tasgaon	3 ·57	3 ·00	3 ·00	3 ·57	3 2·26	10 4·01	10 2·75	10 3·37	10 3·65	8 5·08	3 ·21	3 1·11	23·58	13·78	62–71		G. S.

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
208	KRISHNA, Left Slope —*cont.*	Khánápur	3 1·15	3 ·00	3 ·00	3 ·60	3 1·98	11 3·63	11 3·34	11 4·48	11 3·21	3 4·52	3 1·04	3 1·71	25·66	14·66	1800+ 61–71		G. S.
209		Waruj	3 1·69	3 ·00	3 ·08	3 ·40	3 ·49	11 3·77	11 2·24	11 3·73	11 3·80	3 7·53	3 ·53	3 ·71	24·97	13·54	61–71		G. S.
210		Másur						5 5·65	5 4·54	5 5·25	5 2·37					17·81	62–66		S.
211		Koregaon	3 2·18	3 ·00	3 ·00	3 ·60	3 1·14	11 6·19	11 6·41	11 5·62	11 2·68	3 4·39	3 ·41	3 ·38	30·00	20·90	61–71		G. S.
212		Wai	3 1·38	3 ·00	3 ·00	3 ·71	3 1·50	11 6·66	11 7·15	11 5·74	11 3·05	3 4·38	3 1·34	3 ·52	32·43	22·60	61–71		G. S.
213	KRISHNA, Right Slope.	Hungund	3 ·00	3 ·00	3 ·16	3 ·00	3 ·65	10 2·54	10 2·61	10 3·35	10 5·03	5 2·20	3 ·49	3 ·00	17·03	13·53	62–71	1	S.
214		Bádámi	3 ·00	3 ·00	3 ·45	3 ·00	3 2·28	10 2·15	10 1·73	10 4·23	10 3·81	3 3·81	3 ·20	3 ·50	19·16	11·92	62–71	1	G. S.
215		Nadgund	3 ·68	3 ·00	3 ·25	3 ·42	3 3·04	10 3·65	10 1·50	10 2·99	9 2·59	5 5·69	3 ·42	3 ·67	21·90	10·73	62–71	1·12	S.
216		Nawalgund	3 ·61	3 ·60	3 ·36	3 ·56	3 1·71	10 4·67	10 2·56	10 3·82	10 4·09	5 4·54	3 ·10	3 ·57	23·59	15·14	62–71	1·00	S.
217		Saundatti	3 ·33	3 ·00	3 ·22	3 ·24	3 2·24	10 4·20	10 2·08	10 2·96	10 2·89	5 6·31	3 ·39	3 ·88	22·74	12·13	62–71	1	S.
218		Sampgaon	3 ·51	3 ·00	3 ·18	3 1·35	5 1·97	10 5·12	10 3·65	10 3·42	10 2·26	5 5·11	3 0·71	3 ·45	24·73	14·45	62–71	1	S.
219		Khánápur	2 ·60	2 ·00	2 ·15	2 2·52	2 1·72	2 14·78	2 19·78	2 7·90	2 4·68	2 7·33	2 1·73	2 ·00	61·19	47·14	70–71	1	S.
220		Belgaum	22 ·20	22 ·03	22 ·38	22 1·97	24 3·33	26 10·93	26 14·59	27 9·61	27 3·10	24 4·66	22 ·75	22 ·51	50·06	38·23			C.*
		Observatory	17 ·12	17 ·00	17 ·45	17 2·05	17 3·26	17 11·23	17 15·69	17 11·01	17 2·84	17 4·90	17 0·75	17 0·56	52·86	40·77	56–72		O.
		Civil Hospital	5 ·49	5 ·13	5 ·14	5 1·69	7 3·51	9 10·35	9 12·50	10 7·22	10 3·55	7 4·07	5 ·76	5 ·33	44·74	33·62	62–64 & 67–73	1·05	S.
221		Bágálkot	3 ·00	3 ·00	3 ·00	3 ·00	3 ·69	10 2·85	10 2·02	10 3·36	10 4·33	3 5·89	3 ·13	3 ·52	19·79	12·56	62–71	1·08	G. S.
222		Kaládgi	2 ·00	2 ·00	2 ·01	2 ·53	2 2·29	5 2·61	5 1·26	5 2·84	6 4·58	3 4·19	3 ·27	3 ·18	18·76	11·29	66–69 72–73	1·00	G. S.
223		Bilgi	3 ·69	3 ·00	3 ·18	3 ·58	3 1·67	6 2·94	6 1·37	6 3·59	6 4·57	3 4·81	3 ·30	3 ·76	21·46	12·47	66–71	1	G. S.
224		Gokák	3 ·24	3 ·00	3 ·22	3 ·47	5 1·85	10 3·07	10 1·11	10 2·17	10 2·54	5 7·09	3 ·12	3 1·26	20·14	8·89	62–71	1·26	S.
225		Chikori	3 ·08	3 ·00	3 ·15	3 ·08	5 1·78	10 4·19	10 3·35	10 2·94	10 2·90	5 5·19	3 ·42	3 1·24	22·32	13·38	62–71	1	S.
226		Alta						2 6·30	2 4·35	2 4·20	2 4·50					19·35	62–63	1	S.
227		Ashta	3 ·31	3 ·00	3 ·00	3 1·23	3 3·28	11 3·67	11 3·28	11 4·07	11 2·82	3 6·82	3 ·71	3 1·09	27·28	13·84	61–71		G. S.
228		Kolhápur	3 3 ·99		3	3	3 3·65	13 7·49	13 9·80	13 6·89	13 3·43	5 4·93	5 ·59	5 ·26	37·43	27·61	61–73	1	G. S.
229		Shirála	3 ·45	3 ·22	3 ·00	3 ·57	3 ·70	10 7·06	10 7·63	10 6·12	10 2·37	3 3·81	3 ·51	3 ·62	30·06	23·18	62–71		G. S.
230		Karád	3 1·26	3 ·37	3 ·00	3 ·28	3 1·70	11 5·58	11 6·46	11 5·45	11 2·55	3 2·46	3 ·51	3 ·49	27·11	20·04	61–71		G. S.
231		Satara	8 1·70	8 ·00	8 ·00	8 ·25	8 0·91	17 8·78	18 12·63	18 8·70	18 3·69	8 3·10	8 1·29	8 0·97	42·02	33·80	61–71		C.
		Civil Hospital	5 1·60	5 ·00	5 ·00	5 ·28	5 ·76	6 8·70	7 13·96	7 7·29	7 5·97	5 3·10	5 1·19	5 1·36	44·21	35·92	67–73	1·15	S.
		Mámledár's Kutcherry	3 1·86	3 ·00	3 ·01	3 ·20	3 1·16	11 8·83	11 11·79	11 9·59	11 2·40	3 3·11	3 1·47	3 ·34	40·76	32·61	61–71		G. S.
232		Medha	3 2·03	3 ·00	3 ·00	3 ·53	3 1·54	11 16·12	11 23·59	11 17·05	11 3·91	3 4·49	3 ·32	3 ·41	69·99	60·67	61–71		G. S.

[* The recorded rainfall of Belgaum has just been discovered to be too high, an actual fall of 0·89 inch having been registered by the gauge as one inch.—January 1876.]

TABLE 151—*continued.*

Consecutive Numbers.	River Basin or other Tract.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.
233		Dambal	3 ·34	3 ·08	3 ·63	3 ·48	3 3·43	10 2·90	9 8/31 1·30	9 3/31 2·14	10 2·51	5 5·74	3 ·22	3 ·45	20·22	8·85	1800+ 62–71	1·12	S.
234		Gadag	3 ·45	3 ·25	3 ·46	3 ·75	3 2·68	10 2·78	10 1·63	10 3·58	10 2·74	5 3·94	3 ·33	3 ·93	20·52	10·73	62–71		S.
235		Sawanur	2 1·28	2 ·00	2 ·00	2 ·00	2 3·90	2 4·43	2 3·65	2 3·03	2 2·05	2 8·32	2 ·94	2 ·00	27·60	13·16	70–71		S.
236	TUNGABHADRA, Left slope.	Karajgi	3 ·00	3 ·00	3 ·00	3 ·00	3 2·75	10 3·25	10 3·14	10 3·00	10 2·44	5 5·76	3 ·87	3 ·24	21·45	13·83	62–71	1·37	S.
237		Guttal						6 2·26	6 1·91	6 2·75	6 3·51	2 6·18				10·43	63–68		S.
238		Ránibennur	3 ·41	3 ·00	3 ·00	3 ·70	3 2·38	10 3·51	10 2·23	10 2·30	10 1·92	5 5·56	4 ·12	3 ·21	19·34	9·96	62–71	1·00	S.
239		Rattihalli						4 3/30 4·26	4 3·85	5 3·60	4 1·77					13·48	62–66		S.
240		Hirekerur	3 ·38	3 ·00	3 ·00	3 ·18	3 1·75	5 3·85	5 3·11	5 2·93	5 1·26	5 4·81	3 ·32	3 1·42	20·01	11·15	67–71	1·17	S.
		PART 2. STATIONS known or supposed to be on or in the NEIGHBOURHOOD of EXTRAORDINARY ELEVATIONS.																	
241		Meting	2 ·84	2 ·15	2 ·85	2 ·00	2 ·00	2 3·93	2 7·88	2 1·06	2 4·98	2 ·00	2 ·00	2 ·00	19·69	17·85	69–70		S.
242		Mount Abu	6 ·40	6 ·25	6 ·40	6 ·04	5 ·47	5 9·32	5 20·42	5 35·32	5 5·37	5 8·40	5 ·12	5 ·02	80·53	70·43	62–67		M.
243		Edar	4 ·00	4 ·00	4 ·00	4 ·00	4 ·37	4 3·48	4 16·13	4 12·54	5 5·93	5 ·16	5 ·12	5 ·00	38·73	38·08	69–73	1·00	S.
244		Kuranja	1 ·00	1 ·00	1 ·00	1 ·00	1 ·00	2 20·75	2 29·40	2 24·00	2 14·58	2 3·07	1 ·00	1 ·00	91·80	88·73	68–69		S.
245		Matheran	4 ·00	4 ·00	4 ·00	4 ·00	4 ·09	5 60·30	6 110·63	6 71·71	6 37·33	6 5·02	·00	5 ·00	285·08	279·97	68–73		G. S.
246		Bársi	3 ·00	3 ·00	3 ·00	3 ·00	3 ·55	10 4·92	10 4·15	10 5·58	10 8·38	3 4·73	3 ·95	3 ·00	29·26	23·03	62–71	1·00	G. S.
247		Purandhar	3 ·10	3 ·05	3 ·09	3 ·83	2 6·29	3 5·96	3 13·06	3 18·29	3 4·70	3 2·96	3 1·62	3 ·09	54·04	42·01	56–59		M.
248		Ráygarh						5 25·91	5 46·63	4 37·25	4 15·77					125·56	62–66	1	G.
249		Mándhardeo							2 15·52	2 13·35	2 5·11	1 11/31 5·75					63–64		M.
250		Mahableshwar	3 2·39	3 ·00	3 ·03	3 ·66	3 2·17	11 44·25	11 92·76	11 73·53	11 26·67	3 7·91	3 1·32	3 ·18	251·87	237·21	61–71	1	G. S.
251		Pánchgani	3 2·37	3 ·00	3 ·04	3 1·00	3 1·66	6 17·82	6 17·37	6 13·93	6 4·63	5 4·88	4 ·84	3 1·02	65·56	53·75	66–71		S.
252		Patan	3 ·89	3 ·00	3 ·00	3 ·25	3 1·06	9 13·93	10 20·41	10 15·35	10 4·36	3 6·23	2 ·75	2 ·33	63·56	54·05	62–71		G. S.
253		Vishálgarh						2 16·50	2 14·35	2 13·75	2 4·00					48·60	62–63	1	S.
254		Panhála						2 18·21	2 15·56	2 15·29	2 7·05					56·11	62–63	1	S.
255		Baura						2 55·70	2 93·57	2 46·72	2 46·83					242·82	62–63	1	S.
256		Bhudhargarh						2 33·77	2 26·17	2 23·70	2 12·73					96·37	62–63	1	S.
257		Páchhápur						5 10·54	5 12·11	5 9·10	5 1·84					33·59	62–66	1	S.
258		Sirsi	3 ·77	3 ·26	3 ·09	3 ·92	3 1·01	13 22·86	13 33·95	13 22·92	13 12·74	3 6·19	3 ·88	3 1·05	103·64	92·47	61–73	0·98	G. S.
259		Siddápur	3 1·06	3 ·00	3 ·00	3 ·67	3 1·48	9 30·05	9 45·46	9 23/31 23·15	10 8·06	3 7·96	3 1·78	3 ·48	120·15	106·72	62–71		G. S.
260		Karwar	3 ·54	3 ·00	3 ·00	3 ·24	3 3·19	13 32·06	13 36·85	13 20·54	13 10·75	3 4·36	3 ·65	3 ·30	109·48	100·20	61–73	1	G. S.

TABLE 151—*continued.*

Consecutive Numbers.	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual Average.	Average of Monsoon Months, June to September.	Period of Observation.	Correcting Factor.	Sources of Records from which Averages have been derived.	In what District.
	PART 3. STATIONS whose RETURNS are INCONSISTENT with those of groups of neighbouring Stations, and which have been excluded in calculating the average Rainfall of the several Districts.																		
261	Mahidpur							2 13·07	2 11·97	3 11·14	3 ·94					1800+ 67, 70, & 71		M.	
262	Mehmadabad	3 ·00	3 ·00	3 ·00	3 ·12	3 1·01	3 2·03	3 8·53	3 9·73	3 2·49	3 ·00	3 ·24	3 ·00	24·15	22·78	64–71		G. S.	
263	Dákor							3 16·09	3 9·31	3 6·85						68–72		M.	
264	Nápad							3 5·53	3 10·63	3 5·49	3 2·32				23·97	61–63	1	G.	
265	Baglan	3 ·85	3 ·00	3 ·00	3 ·00	3 ·42	11 3·81	11 3·39	11 3·55	11 2·91	3 3·83	3 1·48	3 ·00	20·24	13·66	61–71		G. S.	
266	Umbárgam	3 ·00	3 ·00	3 ·00	3 ·00	3 ·25	4 12·64	5 19·48	5 12·79	5 7·87	3 3·00	3 ·60	3 ·00	56·63	52·78	67–71	–1·14	G. S.	
267	Supa						5 1·77	5 0·86	5 1·04	5 1·87					5·54	62–66		G.	
268	Malwan	3 ·00	3 ·00	3 ·00	3 ·13	3 1·12	10 23·16	10 22·64	10 16·70	10 7·98	3 4·36	3 ·25	3 ·00	76·34	70·48	62–71	1·00	G. S.	
269	Shiggaon	3 ·48	3 ·00	3 ·00	3 ·17	3 2·84	10 4·23	10 4·28	10 3·32	10 1·35	5 4·36	3 1·90	3 ·45	23·38	13·18	62–71		S.	
	PART 4. STATIONS whose RETURNS are EXTRAVAGANTLY IRREGULAR from Year to Year, and which have been made no further use of.																		
270	Mándvi (Cutch)						3 ·67	3 14·64	3 1·83	2 ·17					17·31	69–70 69–70 & 73		S.	
271	Viramgám	3 ·00	3 ·00	3 ·04	3 ·00	3 0·83	4 1·77	4 5·11	4 8·90	4 4·87	4 ·00	3 ·16	3 ·03	21·71	20·65	68–71	2⅛	G. S.	
272	Pálitána						8 12·37	8 13·50	8 2·50							61–68		G.	
273	Jetulpur						2 5·54									63–64		G.	
274	Saswad	3 1·87	3 ·00	3 ·00	3 ·20	3 1·80	10 2·51	10 2·14	10 2·92	10 2·29	3 4·52	3 0·65	3 ·74	19·64	9·86	62–71	1·12	G. S.	
	PART 5. STATIONS whose EXACT POSITIONS the COMPILER has been unable to find.																		
275	Sonpurree						2 2·43	2 10·63	2 16·25	2 5·02					34·33	67–68		G.	Kattywar.
276	Mánákwára						2 2·16	2 6·65	2 8·00	2 3·04					19·75	67–68		G.	Kattywar.
277	Sadra	5 ·00	5 ·00	5 ·00	5 ·00	5 ·21	13 4·06	13 10·35	13 13·52	13 3·38	5 ·44	5 ·11	5 ·03	32·10	31·31	61–73	1·16	G. S.	Mahi Kánta.
278	Bhanaseemul	2 ·08	2 ·12	2 ·00	2 ·00	2 ·00	2 3·85	2 10·87	2 8·40	2 1·85	2 ·32	2 ·21	2 ·00	25·70	24·97	70–71		S.	Rewá Kánta.
279	Wasna	2 ·00	2 ·00	2 ·00	2 ·00	2 ·00	2 5·10	2 20·18	2 9·65	2 1·41	2 ·44	2 1·44	2 ·00	38·22	36·34	70–71		S.	Rewá Kánta.
280	Pandoo Thana	3 ·00	3 ·00	3 ·00	3 ·00	3 ·00	3 2·47	3 14·86	3 7·70	3 11·20	3 ·68	3 ·00	3 ·00	36·91	36·23	69–71	1·09	S.	Rewá Kánta.
281	Nayakhede	2 ·08	2 ·00	2 ·00	2 ·23	2 ·23	2 2·33	2 1·02	2 ·55	2 1·48	2 1·13	2 ·08	2 ·00	7·13	5·38	70–71		S.	Násik.
282	Hiwut						5 4·20	5 3·58	5 4·49	5 1·75					14·02	62–66		G.	Poona.

In combining the results of independent registers kept at the same town, to find the general monthly averages which have been adopted, weights have been given to the separate monthly averages proportional to the number of months from which they were derived.

259. The next step taken was to dot out upon skeleton maps the positions of the several stations, taking a separate map for each of the months May to November, and to mark opposite the several dots the average rainfall of the respective months. This was done with respect to all the stations included in Part 1 of Table 151. By an inspection of the numbers in the monthly and annual maps, lines were now drawn with a free hand, so as to enclose groups of stations whose rainfall was nearly of the same amount for the same group, until all the stations were, as far as was practicable, so enclosed. The averages were then calculated of the numbers within the closed curves, giving the weight unity to all numbers derived from a single register, and a weight equal to the square root of the number of registers in cases like Bombay, where the numbers are derived from several independent registers. In such cases it is evident that a greater value attaches to the results than in the case of stations at which a single gauge only is observed; at the same time the multiple gauges of such stations are crowded together in the same locality, whilst the single-gauge stations have the advantage of being well spread over the country; hence the weight given to combined results should be greater than unity, but less than the number of registers, and the square root of the number of registers combined has been adopted as near enough for the present purpose.

260. The monthly and annual maps described are copied in Plates LXXI. to LXXVIII., but with the following modifications:—

On the monthly maps—

(1.) The stations are generally marked by dots only, the numbers being omitted; and the average numbers marked within the several enclosures refer only to stations dotted, but not individually numbered; but

(2.) Numbers which differ considerably from those of any near groups, or which belong to stations whose dots lie within the enclosures, and which differ from the means of the respective groups by more than 2·00 inches, are marked opposite the respective dots; and the latter of such numbers, together with the corresponding dots, are surrounded in each case by a small violet ring.

(3.) The numbers are marked for all the stations included in Part 2 of Table 151, and the dots are enclosed by small violet circles to distinguish these stations, which are peculiarly situated, from others.

On the annual map—

(4.) A number is marked opposite the dot of every individual station, representing, when unenclosed, the average rainfall for the whole year, and when enclosed in square brackets thus [ ], the average for the monsoon months, June to September only; but no dots are marked for stations for which we have no monthly averages for any of the months June to September.

(5.) Numbers differing from the averages of enclosed groups by 5·00 inches or more are surrounded singly, together with the corresponding dots, by small violet rings.

(6.) Same as (3).

(7.) The averages of enclosed groups are calculated after the exclusion of numbers which come under the categories (5) and (6).

On both monthly and annual maps the violet lines enclosing groups of stations are drawn so as to exclude, as far as possible, stations whose rainfall differs largely from that of any near groups, such unenclosed stations being left to speak for themselves singly.

None of the stations or numbers included in Parts 3, 4, and 5 of Table 151 are marked in any of the maps.

261. The lines which surround stations of nearly equal rainfall, as well as the numbers representing the average rainfall of the groups of stations, are made in violet ink; and the object of the grouping is—by removing from the maps a great number of slightly discordant numbers (which, however, may be seen in Table 151) which could only bewilder the reader—to present before the eye, in concise form, as complete a picture of the actual distribution of rainfall as the observations are capable of affording at one view. The water partings of the great river basins, and the courses of the rivers, are marked on the maps, the former in black lines consisting of dots and dashes, and the latter in continuous black lines, to show the intimate connection subsisting between these, the principal features of the physical geography of the country, and the distribution of rainfall. It has neither been convenient, however, on account of the small scale of the skeleton maps available, nor are the materials deemed to be sufficient to justify any attempt to define rigidly the limits of areas of nearly equal rainfall; the averages of groups must therefore be understood to refer to the stations marked as included in them, and the enclosing lines as guiding the eye quickly to the form and extent of the districts which the several groups of stations may be taken to represent.

To avoid repetition we shall nevertheless freely use such expressions as "rainfall of a district," "temperature of a district," &c., meaning no more by them than "the rainfall of the district to the extent to which the mean rainfall of our stations in it may be accepted as representing that of the district," &c. In regard to rainfall the registers are so numerous, and in such fair general accord, that the need to guard by this remark against misapprehension applies only to districts here and there, but it is of greater generality as regards temperature and wind.

Notes on the Distribution of Rainfall in different Months.

262. May.—The rainfall of May is greatest at our most southern coast stations, being about four inches in the Karwar-Honawar neighbourhood. It diminishes as we follow the coast northward to about half an inch near Bombay, and then increases to an inch in the inlet of the Gulf of Cambay and lower course of the Sábarmati river. To the eastward of this line in Guzerat the rainfall is insignificant. There is a less fall than one inch in the north of the Deccan, and less than two inches in the Deccan south of the Krishna river, except along the southern part of the edge of the Ghaut, where the average is about three inches; the eastern side of the southern half of the Deccan has less than half the quantity of rain that falls on the western side. The Ghaut border of the Deccan, between Poona and Belgaum, has more rain than the Konkan below it; but ascending the Ghaut from

Karwar the rainfall diminishes inland to 1½ inches, and then increases to 2½ inches; and northward of Bombay there is little difference between the falls in the Konkan and Deccan. On the Malwa plateau and in Upper Sind the fall is less than half an inch. Lower Sind is all but rainless.

263. June.—Excepting the edge of the Ghauts, the coast south of the Konkan has still the largest rainfall, the average of Coompta and Honawar being 42 inches. There is a gradual diminution on the coast northward, reaching 21 inches about Bombay, and 14 inches in the north of the Konkan, and continuing up to the Sábarmati valley, the lower half of which has a rainfall of three inches. In Guzerat the fall increases on approaching towards the Malwa plateau to six inches; and on that plateau it diminishes from six inches on the southern edge to three inches on the northern edge. On the edge of the Ghauts we have falls ranging up to 56 inches, but with this exception the rainfall of the Deccan bears now but a small proportion to that of the Konkan, varying from a third in the north to a tenth in the south. The average fall is about three inches on the eastern side of the Deccan, and it increases to about double that amount on the Ghaut border, exclusive of the very edge. In the Upper Tapti valley a fall of four inches is increased by an inch on ascending further up the valley. Branching off from Guzerat towards Sind, the decrease of rainfall continues to Upper Sind, where it is less than half an inch, but in Lower Sind it is somewhat more than half an inch.

264. July.—The fall has increased since June everywhere but in parts of the Deccan; and the highest fall on a Ghaut station has reached 94 inches. The distribution in the Konkan is still the same, the averages being—of Coompta and Honawar 46 inches, about Bombay 24 inches, of the Konkan north of Bombay about 22 inches, and at the mouth of the Tapti river 13 inches. In Guzerat there is a nearly uniform fall of about 10 inches, but with an excess of four inches in the same region, towards the Malwa plateau, where an excess was found in June. On the Malwa plateau the average fall has reached nine inches, with still a slight defect on the northern edge. In Malwa and Guzerat the rainfall is quite double that of June; in the Upper Tapti valley the increase is less considerable; and on the eastern side of the Deccan there is a marked decrease. A remarkable feature first presents itself within our boundaries in this month. From Dambal in the south to Sirur and onward to Dhulia in the north, along a strip of country the middle of which is from 60 to 90 miles distant from the Ghauts, less rain falls than along parallel strips to eastward or westward of it; and as this feature is not obliterated till the end of the monsoon, though its position changes laterally, we shall for the sake of brevity, in our further references to it, speak of it as the minimum band; its length direction is, in a rough sense, parallel to the line of the Ghauts. The fall of the minimum band varies from 1½ inches in the south to three or four inches in the north, and the corresponding variations to eastward of it are from 2½ inches to six inches. The increase towards the Ghauts is large, but especially so in the south. As in June, there is a gradual decrease in the fall in proceeding from Guzerat towards Sind, but the absolute fall in Upper Sind has reached one inch; further south it is 1½ inches, and in Lower Sind 2½ inches.

265. August.—The rainfall of the Konkan shows a decrease as compared with that of July. The average for Honawar and Coompta is 26 inches, and it decreases northward; but

from Bombay northward the Konkan has a nearly uniform fall of 16 inches; beyond,—throughout Guzerat, but with excess in the same district as in June and July,—the average is about 10 inches as in July; a sensible decrease is, however, shown in the upper parts of the Mahi basin. No change appears in the Upper Tapti valley. The fall in the Malwa plateau is eight inches in the southern half, diminishing to five inches on the northern edge. The fall on the Ghaut border of the Deccan has diminished since July to southward of Wai, but remains unchanged to northward of Wai; the largest fall at a Ghaut station is 74 inches. The minimum band occupies the same position and is of the same extent as in July, but the amount of its rainfall has increased in the southern half to the extent of doubling the fall of July; indeed the increase is general on the eastern side of the Deccan, from the basin of the Godavari southward. The decrease from Guzerat towards Sind is still gradual, but the rainfall of Umerkot and Upper Sind is about double that of July; and the maximum fall of Sind is now decidedly in the district between Hyderabad and Mehar, the decrease from thence to the most northerly group of stations being from three inches to one inch.

266. September.—Except in the Deccan, there is everywhere a decrease, and generally a large decrease, of rainfall since August. The coast of the Southern Konkan has an average fall of about 10 inches; from Bombay northward to the Sábarmati valley the fall diminishes to three inches. In the Mahi basin the distribution is similar to that of August, but the amount of fall only about half. In the Upper Tapti valley there is a decrease of three inches. In Malwa we have on the southern edge seven inches of rain, and on the northern edge four inches. The minimum band has approached to 40 miles distance from the Ghauts in the south and still nearer in the north of the Deccan; its rainfall rises from $2\frac{1}{2}$ inches in the south to four inches in the north. The rainfall of the eastern side of the Deccan is nearly the same as in August, but that of the Ghaut border is much diminished; the highest fall at a Ghaut station is, in this month, 47 inches. The average rainfall of Sind is about one inch, and it is largest on or near the coast. In the preceding monsoon months the fall has always been greater in the Umerkot district than at Kurrachee.

267. October.—The average rainfall of the North Konkan is two inches, increasing southward to four inches at Goa and seven inches at Coompta. In Guzerat the average fall is about half an inch, but more rain falls, as usual, higher up the valleys than near the outlets of the rivers. At the mouths of the Nurbudda and Tapti rivers one inch is the average fall, and in the Upper Tapti valley it is two inches. In Malwa a fall is shown of one inch on the south edge and a quarter of an inch on the north edge of the plateau. The Deccan has now generally a considerably larger fall than the Konkan; the minimum band has reached to near the edge of the Ghaut, and extends only from Satara to Belgaum. On its eastern border there is now a maximum band which is prolonged southward to Sirsi. The rainfall of this band is $6\frac{1}{2}$ inches; and it again is succeeded on the east by groups of stations of smaller rainfall than itself, but increasing from north to south. There is a considerable increase since September in the fall of the southern half of the Deccan, but little change in the northern half. In Sind the rain has quite ceased, Kurrachee being the only exception, and that with an insignificant fall.

268. November.—South of Dápoli the fall of the Konkan is less than one inch, and north of Dápoli to Ahmedabad the average is less than half an inch. Eastward of this line, and north of the Vindhyá mountains, the rain has practically ceased, though for Mhow and a few

other places small fractions still appear. The fall on the Deccan is still greater than that on the Konkan. The south-eastern corner of the Deccan has the lowest fall,—a quarter of an inch; and in other parts the average is about one inch, with some tendency to a diminishing fall eastward.

269. The rainfall of the months December to April is very small, and cannot be said to be correctly represented by the average numbers of our tables, which for those months are generally derived from observations extending over but short periods, and which, moreover, are in some cases rather the rainfall of a particular storm divided by the number of years of observation than numbers expressive of a general liability to the occurrence of rain in the respective months in successive years. Nearly the whole of the rainfall for the Deccan and Konkan shown by the tables for the month of January, for example, is of this nature, being due chiefly to a storm which occurred between the 13th and 17th January 1871; a storm the track of which is distinctly marked out by plotting the rainfall upon a map.

270. The average rainfall of the full year is shown by the map, Plate LXXVIII. On the coast, south of the Konkan, we find at Honawar a fall of 152 inches. Northward there is a rapid diminution—to 112 inches at Vingorla and 73 inches in the neighbourhood of Bombay; beyond which the North Konkan has a nearly uniform average fall of 68 inches. Of stations near the foot of the Ghauts, those between Sunderwari and Ráygarh have an average fall of about 130 inches; those between Mangaon and Kurjat an average of about 110 inches; and at Mokhára the fall is 95 inches. At stations on the edge of the Ghauts we have falls of 252 inches at Mahábleshwar, and 104 inches at Igatpura; and during the months June to September only, we have falls of 96 inches at Bhudhargarh, 243 inches at Baura, and 49 inches at Vishalgarh. At Matheran the average recorded fall is larger than at any other station in the Presidency, viz., 285 inches. At the mouth of the Tapti river the fall has diminished to 42 inches, and beyond this northward to far up the Sábarmati river the fall varies but an inch or two from an average of 30 inches. Up to the high ground on the left basin of the Mahi river there is, however, a gradual increase reaching 43 inches, and beyond it, in the Malwa direction, a decrease to 29 inches. In the extreme north of Guzerat the rainfall has decreased to 27 inches, and at Mount Abu the average is 81 inches. In Kattywar we have an average of 24 inches, but with an excess of four inches at the somewhat elevated station of Rajkot. In the Umerkot district, in Sind, the yearly rainfall has gone down to 10 inches, in the Indus valley from Hyderabad to Mehar to seven inches, and in Upper Sind to four inches. Kurrachee and the line of railway to westward of the Sattara hills have an average yearly fall of 10 inches; but the district intervening between the eastern part of the Sind Railway and the Indus, and across the Indus to Tándo Aláhyar, appears to have an average fall of less than half that of the surrounding country in any direction. In South Malwa we have an average of 32 inches, and on the northern edge of the plateau 21 inches. In the Upper Tapti valley the annual average is 24 inches. On the Deccan we have low falls of 20 inches in the southern half of the Kaládgi district, and on the eastern slopes of the Dharwar district, and increasing rainfall as the Ghauts are approached. A district of low falls of about 20 inches is also found near the course of the Bhima river from Sirur to Pandharpur, and at Niphád and Vinchur near the course of the Godávari. Small groups of stations on the eastern side of the Deccan have a greater rainfall than the middle region. The fall of the latter varies from 23 inches on the

eastern side of the Belgaum district to 25 inches on the water-parting which separates the higher portions of the basins of the Godávari and Bhima rivers, whilst the groups before referred to, which lie, one near the Bhima river, one near a lower part of the water-parting of the Godávari and Bhima, and the third on the upper northern slopes of the basin of the Tapti river, have falls of 27, 28, and 29 inches respectively. It would appear from the nearness with which groups of moderate rainfall under 30 inches approach the Ghauts on the northern border that the region of excessive rainfall on the Deccan side of the edge of the Ghauts is very narrow. In this respect the northern and southern halves of the Ghaut border are in marked contrast.

Progress and Decline of the Monsoon.

271. Regions north of the Tapti valley (inclusive).—In an average year the rainfall increases in Upper Sind and in Lower Sind, east, till the month of August; in Lower Sind, west, in the higher Mahi basin, and in Malwa till July, with but little diminution in August. On the coast of the Gulf of Cambay, and continuing up the Sábarmati valley, the rainfall is sensibly the same in July and August. In September the decrease of rainfall is large everywhere, except in the Upper Tapti valley, where it is only moderate. After September the decline continues to the end of the monsoon.

272. The Konkan.—In the Vingorla-Goa neighbourhood the heaviest rainfall of the year occurs in June and July, the two months having nearly the same fall; but southward of this from Karwar to Honawar, where the Ghauts approach close up or near to the coast, July is decidedly the most rainy month; it is also the month of maximum rainfall throughout the Konkan to northward of Vingorla; and after July the rainfall declines everywhere till the end of the monsoon.

273. The Deccan.—There is a large increase in the rainfall of June, as compared with that of May, everywhere, except in the east side of the Dharwar district. At stations on the edge of the Ghauts the rainfall increases till, and the maximum occurs in, July. Away from the edge eastward and south of the Godávari there is a general decrease in the rainfall from June to July over the greater half of that part of the Deccan. From the Godávari to the southern watershed of the Krishna there is a general increase from July to August, except on the Ghaut border, where there is a general decrease between those months, but the decrease is but a slight one in the northern half of the border. South of the Godávari there is a slight increase of rainfall from August to September on the eastern side, but a decrease in the minimum band and Ghaut border. Along the course of the Bhima river and in the neighbourhood of Bijapur there is a considerable decrease in the rainfall from September to October, but in the Dharwar district there is a considerable increase, and along a line extending from Yellapur in the North Canara district to Waruj in the Satara district a large increase from the former to the latter of those months.

274. In Sind the monsoon begins late and ends early, being scarcely perceptible except in the months June to September. In the average year it appears to be felt along the whole of the Konkan, in the Gulf of Cambay, and in the lower Sábarmati valley in the month of May, but scarcely so in other parts of Guzerat. In October we find but little trace of it in Guzerat, but in the Konkan this month contributes four or five per cent. of the total yearly

rainfall. The proper south-west monsoon is everywhere confined within the months May to October, beginning late in the former month and ending early in the latter, if felt at all. But the Deccan is subject to rainfall during, towards the close of, and after the south-west monsoon, which belongs to a different system, and to which must be attributed the excess rain that falls on the eastern side of the Deccan in July, as compared with more westerly regions; the increase of rain in the south and south-east towards the close of the south-west monsoon; and the travelling, in a south-south-west direction, which is obliquely inclined to its own length, of a band of maximum rainfall.

275. To obtain further information about the progress of the south-west monsoon at its commencement from south to north, along and near the coast of the Konkan, we have calculated from the data at our command the average dates when the accumulated rainfall, reckoning from the 1st May, first reached *one inch*.

The following table shows the results of these calculations for the several stations in the order of their latitudes.

TABLE 152.

AVERAGE DATE at which the ACCUMULATION of RAINFALL since the 1st May first reached *one inch*.

Station.	Latitude.	Average Date.	For Groups of Stations.	
			Average Date.	Mean Latitude.
	° ′			
Kurrachee	24 45			
Bhuj	23 17	22nd June.		
Broach	21 41	23rd June.		
Gogo	21 39	16th June.		
Mándvi	21 18	16th June.		
Surat	21 10	15th June.		
Mahim	19 42	12th June.		
Bassein	19 20	8th June		
Panwel	18 59	7th June	8th June	° ′ 18 57
Bombay	18 53	9th June		
Alibag	18 36	8th June		
Dápoli	17 48	6th June		
Mandangarh	17 42	2nd June		
Guhágar	17 28	4th June	5th June	17 32
Malgund	17 10	8th June		
Ratnágiri	17 0	4th June.		
Rajapur	16 42	4th June.		
Malwan	16 3	4th June.		
Vingorla	15 51	2nd June.		
Karwar	14 49	27th May.		
General Average date		9th June.		

Instead of taking these dates with reference to a fall of a fixed and uniform quantity of rain for all the stations, it would be more appropriate to vary the quantity (say) proportionally to the total annual rainfall; but this and other obvious refinements are dispensable in a first inquiry of this kind. The regularity of the dates is remarkable. As the sun first goes to northward of the zenith of Karwar on the 30th April, and northward of Bhuj not till the 14th June, it is clear that the rains, when once begun, travel northward much more rapidly than the sun; there is, as it were, a piling up of the conditions favourable to the formation of rain, to be let loose with a bound when the climax is reached.

PART IV.

THE CLIMATE OF THE PRESIDENCY, AND ITS VARIATIONS UNDER CHANGE OF PHYSICAL CONDITIONS AND WITH CHANGE OF SEASON.

276. In the three preceding parts of this memoir we have kept with fair consistency to our principle of aiming mainly and immediately at the establishment, by means of the observations under discussion, of phenomenal laws. In the efforts that we shall now make to connect together some of the general phenomenal results that we have arrived at, we shall not confine ourselves to generally adopted lines of reasoning on meteorological questions, although at the same time it will be necessary, to avoid intolerably tedious verbiage, to content ourselves with the endeavour to make intelligible the ideas that we have to express, without fencing round every position by systematically forestalling plausible objections. If in this first effort we succeed in conveying to our readers our own general conviction of the correctness of the notions that we have to advance—or at least of their being nearer the truth than older views which still find common expression in the writings of meteorologists of some eminence—we shall have attained our present object.

Contour of the Country.

276*a*. A first requisite of an intelligent study of the climate of any country is a knowledge of some other elements of its physical geography, and especially of its geographical situation and form, the character of surrounding countries or seas, its mountain ranges and river courses, and some general notion of the variation of its absolute elevation above mean sea level. The source from which we have obtained the best information regarding the general contour of the whole of India, and of its division by natural drainage into great river basins, is Mr. Trelawny Saunders's "Sketch of the Mountains and River Basins of India;"* consisting of two maps with explanatory memoirs. In our map (forming Plate LXXIX.) of the Bombay Presidency we have followed the delineation of the water-partings of the great river basins adopted by Mr. Saunders, with only such small modifications as the larger scale of our map admits of our introducing. In making these modifications we have been guided by the drainage shown in a "Preliminary Map of the Bombay Presidency," published under the direction of the Surveyor General of India in July 1874, which map is on a scale of 32 miles to 1 inch. For the principal contributions to the heights marked upon the map, those, namely, of the stations along the lines of railway, we are indebted to Mr. C. Ward, Acting Chief Engineer of the Great Indian Peninsula Railway, to Mr. F. Mathew, Acting Agent and Chief Resident Engineer of the Bombay, Baroda, and Central India Railway, and to Mr. Charles Cheyne, Engineer in Chief of the Holkar and Nimach State Railway. The heights are taken from printed lists compiled by Major T. F. Dowden, R.E., Consulting Engineer for Railways, Bombay, from which

* Published by W. H. Allen and Co., London, 1870.

compilation we learn that the zero to which they refer is 80·3 feet above the Town Hall datum, Bombay, the adopted depth of the datum below mean sea-level being 80·3 feet. A bench mark at the north end of the steps of the Town Hall fixes a position 100 feet above the datum.

276*b*. The following list shows the heights (to the nearest foot) extracted from Major Dowden's compilation, and the places may be readily identified on the map by the order of succession of the numbers representing the heights.

GREAT INDIAN PENINSULA RAILWAY.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Coorla	12	Mhasáwad	717	Shegaon	910	Urun	1,80
Tanna	25	Jalgaon	689	Akola	917	Kedgaon	1,781
Kalyán	26	Nésirabad	681	Murtizapur	986	Pátas	1,[illegible]
Titwála	56	Bhusawal	677	Badnera	1,093	Dhond	1,68[illegible]
Wássind	101	Sanda	709	Amraoti	1,110	Diksal	1,6[illegible]
Shábápur	244	Ráver	790	Chandur	1,076	Pomalwari	1,629
Átgaon	476	Burhánpur	854	Pulgaon	879	Jeur	1,714
Khardi	750	Chándni	889	Wardhá	930	Keni	1,785
Kására	1,130	Dongargaon	1,214	Hingunghaut	746	Barsi Road	1,68[illegible]
Igatpuri	1,922	Khandwa	1,007	Sindi	802	Mádha	1,57[illegible]
Ghoti	1,896	Bir	952	Bori	865	Mohol	1,49[illegible]
Nandur	1,891	Kirkian	915	Nagpur	1,006	Sholápur	1,496
Násik	1,843	Sioni	1,024	Badlápur	68	Hudgi	1,538
Kherwári	1,811	Itarsi	1,069	Neral	129	Karabgaon	1,483
Niphád	1,806	Bágra	1,101	Karjat	174	Gudur	1,443
Lasalgaon	1,942	Sohágpur	1,103	Campooly	232	Kulbarga	1,492
Manmad	1,898	Barkeri	1,159	Khandála	1,793	Sháhábád	1,310
Nándgaon	1,552	Gadarwára	1,158	Lonauli	2,037	Nalwár	1,326
Naydongri	1,390	Warangaon	723	Kharkala	2,000	Yádagiri	1,198
Chálisgaon	1,139	Nargaon	957	Talegaon	2,015	Saidápur	1,230
Kajgaon	966	Malkápur	816	Chinchwad	1,876	Krishna	1,140
Páchora	852	Nándura	865	Kirkee	1,839	Chikságar	1,175
Maheji	792	Khangaum	998	Poona	1,819	Raichur	1,315

BOMBAY, BARODA, AND CENTRAL INDIA RAILWAY AND EXTENSION.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Máhim	9	Virar	18	Gholwad	35	Bulsar	48
Bandora	12	Sappála	18	Sanjan	54	Dungri	51
Andheri	40	Palghar	52	Bhilad	105	Bilimora	34
Borwali	47	Boisar	50	Damanj Road	96	Amalsád	43
Bassein	31	Dáhánu	32	Párdi	50	Nausari	37

BOMBAY, BARODA, and CENTRAL INDIA RAILWAY and EXTENSION—*continued.*

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Sachin	41	Meagam	94	Dákor	178	Patri	50
Surat	59	Karwan	106	Nariad	123	Sabli Road	74
Amroti	61	Mundala	123	Mehmadabad	118	Liláput	87
Sayan	66	Dubhoe	153	Barajree	127	Lakhtar	147
Kim	64	Etola	92	Ahmedabad	173	Wadhwán	238
Panoli	96	Baroda	119	Ámbli	176		
Ankleswar	65	Wásad	130	Sánand	144	Extension.	
Broach	56	Ánand	144	Chárori	119	Jeypore	1,269
Chamárgám	70	Bhaluj	152	Jakhwára	144	Ropera	1,210
Palej	90	Umreth	173	Virámgám	103		

In KATTYWAR.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Jasheepoora	153	Veráwal	10	Bundoory	120	Dhorájee	194

SIND RAILWAY.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Malirri	71	Boondanwaree	170	Jhimpir	91	Kotri	68
Dárbeji	119	Jungsháhi	55	Meting	223		

NIZAM'S STATE RAILWAY.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Wadi	1,405	Illapur	1,423	Illampalli	2,059	Hussain Sagur	1,709
Chitapur	1,392	Tandur	1,492	Pattapur	1,874	Secunderabad	1,763
Seram	1,368	Dharur	1,674	Lingampalli	1,838	Hyderabad (Deccan)	1,662

HOLKAR STATE RAILWAY.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Sanawad	640	Balwara	865	Highest point on Railway line	1,925	Rao	1,900
Barwai	632	Mhow	1,865			Indore	1,801

NIMACH STATE RAILWAY.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Burnagur - -	1,623	Jowra - -	1,537	Nimbhera -	1,439	Rupaili - -	1,312
Fatehabad - -	1,662	Dodar - -	1,588	Chitlor - -	1,312	Sakrani - -	1,313
Oojein - -	1,587	Daloda - -	1,545	Gangrar - - -	1,335	Bhondarwara -	1,360
Runija - -	1,712	Mandesor -	1,426	Hamirghar -	1,348	Násirabad - -	1,410
Bhilpank -	1,615	Nimach - -	1,577	Bhilwara - -	1,362		
Ruttam - -	1,588	Nawagám - -	1,501	Barakdera - -	1,405		

KARWAR STATE RAILWAY.

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Hessurur - -	1,632	Gadag - -	2,134	43rd Milestone from Karwar -	210	Karwar - -	8
Dambal - -	1,926	Yellápur - -	1,777				

Heights reported by the medical officers in charge of the several observatories or dispensaries at which the observations are taken are as follows:—

Kurrachee, 40 feet; Deesa, 408 feet; Poona, 1,992 feet; Belgaum, 2,260 feet; and Násirabad, 1,463 feet. The height given on the printed sheets of observations issued by the Goa Observatory is 7·2 metres = 23 feet. The height of the Ghauts six miles east of Patna (2,515) was taken from "Balfour's Barometrical Sections;" that of Mount Abu (4,500) from the "Indian Traveller's Guide." The height of the Colaba Observatory, Bombay, is 37 feet.

The following heights are taken from a map of India (No. 2) published under the direction of the Surveyor General of India in March 1872, viz.:—

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Tatta - -	39	Udepur - -	2,064	Málegaon - -	1,587	Karnul - -	900
Sehwan - -	117	Dharwar - -	2,423	Samber Salt Lake	1,184	Beder - -	2,330
Lárkána - -	185	Nándur - -	1,276	Mehidpur - -	1,600		
Shikárpur -	194	Bassim - -	1,758	Jálna - -	1,652		
Kusmore - -	246	Aurungabad -	2,143	Mahableshwar -	4,540		

Heights taken from a Report on the Meteorology of India by James Glaisher, Esq., F.R.S., published in the Report of the Royal Commission on the Sanitary State of the Army in India, Vol. I., 1863:—

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Rutnágiri - -	150	Jacobabad - -	220	Sirur - -	1,752	Satara - -	2,320
Dápoli - -	600	Kolhápur - -	1,797	Dhulia - -	1,000	Hyderabad (Sind)	99
Rajkot - -	450						

Heights taken from De Schlagintweit's "India and High Asia," Vol. IV. :—

Station.	Height.	Station.	Height.	Station.	Height.	Station.	Height.
Ajmir - -	1,500	Baitual - -	2,000	Sehor - -	1,620	Kaládgi - -	1,744
Beaver - -	2,000	Hushangabad -	1,050	Ahmednagar -	2,133	Bhuj - -	281
Erinpura - -	1,500	Sagar - -	1,906	Bijápur - -	1,700	Panchgani - -	4,000
Phaltan -	1,700	Purandhar -	3,974				

276*c*. An alphabetical index of the places marked on the map, Plate LXXIX., is given in the Appendix to this memoir; and it shows, besides the latitudes and longitudes of all stations for which data of any kind have been made use of in the compilation, the nature of the information that we possess for each station.

General Notions on Aërial Circulation.

277. We proceed to explain, in the next place, some general notions on aërial circulation, which, in the sequel, will enter largely into the theoretical views that we have to advance.

Topsy-turvy Movements.

Consider a vertical section of a column of air in the midst of an extensive atmosphere, which is in all respects in like condition to the column. Let the atmosphere be in equilibrium, and be distributed in the manner of a perfect gas, acted upon by a constant downward force; that is to say, let the pressure and density diminish approximately in geometrical progression, as the height increases in arithmetical progression. The air at the top of the column considered may or may not be infinitely attenuated. Let an infinitesimal increment of heat be communicated to the bottom layer—supposed to be of very small depth—of each column of the whole extent of atmosphere that we have to do with, and let us consider what will take place in our typical column. As all the columns about it are in the same condition, and have the same infinitesimal increment of heat communicated, and as there was no communication of air from column to column at starting, there will be none after the bottom layer has been heated. The elastic force of the bottom layer will be increased, and it will expand, lifting the column of air above it; its density will thus diminish, and if the diminution be sufficient, it will exchange places with the layer immediately above it; and in making this exchange it will lose heat by reason of the work done by it in expanding, and the layer that descends, which it will be seen later is of the same mass, will gain heat to the same extent in being compressed. It is not necessary, in order that contiguous layers should exchange places vertically, that the lower layer should become less dense than the upper layer; a much less quantity of heat added to the lower layer than would be requisite to make it of the same density as its upper neighbour would suffice to place the two layers in a state of unstable equilibrium, so that if the least disturbance caused them mutually to encroach on each other's places, however little, the encroachment would continue until the two layers had completely exchanged places.

278. To give definiteness to the case that we consider, let us make the area of a horizontal section of our column one square foot, and let the column be divided into layers, each of which contains one grain of air, and in its vertical motion let the mass of each of the layers remain constant, being the same identical and continuous body of matter whatever place it occupy; the thickness of these layers will in all applications that we have to make of the results be small enough to be regarded as infinitesimal. Also let us define as follows :—

p = the barometric pressure of a particular part of the column considered, expressed in inches of mercury of the density which mercury has at the temperature of the freezing point of water, and (it is convenient to say) on the square foot of surface.

t = the temperature of the part of the column whose pressure is p; t is expressed in Fahrenheit degrees, reckoned from a zero which is 459°·1 below the zero of Fahrenheit's scale, a system of reckoning in which the freezing point of water is 491·1.

v = the volume, in cubic feet, of a grain of air at temperature t and pressure p.

V = the volume, in cubic feet, of a grain of air in the merely mathematical case in which $t = 1$ and $p = 1$, calculated by the gaseous laws. Since the weight of a cubic foot of air, at temperature 32° Fahrenheit (= 491·1 on our scale) and pressure 29·914 inches in the latitude of London, is 565·0862 grains,

$$V = \frac{29\cdot914}{491\cdot1} \cdot \frac{1}{565\cdot0862} = \cdot0001078 \text{ cubic foot.}$$

ρ = the density of air at temperature t and pressure p, the substance of unit density being that of which a cubic foot contains one grain, and therefore V times as dense as air under pressure unity and at temperature unity; hence $\rho = \frac{1}{v}$.

K_v = the equivalent of work to the quantity of heat required to raise to the extent of one degree the temperature of a grain of dry air at constant volume: = 130·4 foot-grains.

K_p = the equivalent of work to the quantity of heat required to raise to the extent of one degree the temperature of a grain of dry air at constant pressure: = 183·6 foot-grains.

k_v = the equivalent number of degrees of temperature of a grain of air at constant volume to the work done in lifting a mass of mercury, one inch in height and one square foot in horizontal section, through one foot of height:

$$= \frac{495088 \text{ foot-grains}}{130\cdot4 \text{ foot-grains}} = 3796°\cdot7.$$

k_p = the equivalent to the same amount of work in degrees of temperature of a grain of air at constant pressure : $= \frac{495088 \text{ foot-grains}}{183\cdot6 \text{ foot-grains}} = 2696°\cdot6.$

λ = the ratio of the specific heat of air at constant pressure to the specific heat of air at constant volume: $= 1\cdot408 = (1 + k_v V)$, since V is the increase of volume of a grain of air under pressure unity, due to an increase of 1° of temperature; hence $k_v V = \lambda - 1$,

279. Under all circumstances, and therefore in every part of our typical column, whether in a normal or disturbed condition, the temperature, pressure, and volume of a grain of air will be related to each other in the manner indicated by the equation

$$v = \mathrm{V}\frac{t}{p} \tag{1}*$$

$$\therefore d\,v = \mathrm{V}\left\{\frac{d\,t}{p} - \frac{t}{p^2}\,d\,p\right\} \tag{2}$$

$$p\,d\,v = \mathrm{V}\left\{\frac{d\,t}{d\,p} - \frac{t}{p}\right\}d\,p \tag{3}$$

But the dynamical theory of heat tells us that, in shifting from a place of pressure p and temperature t to a place of pressure $(p + d\,p)$ and temperature $(t + d\,t)$, our grain of air will have had work done upon it, by the compression of it, equal to $-p\,d\,v$; and as k_v is the number of degrees of temperature that a grain of air at constant volume would be increased by work done upon it equal to unity in the value of $-p\,d\,v$, we have

$$-k_v\,p\,d\,v = -k_v\,\mathrm{V}\left\{\frac{d\,t}{d\,p} - \frac{t}{p}\right\}d\,p \tag{4}$$

as the increment of temperature received by the grain of air in consequence of the work done upon it; and if the air rise, the same expression will show the decrement of temperature due to work done by the air during a decrease of pressure and temperature.

280. Now the first effects of directly increasing the temperature of the bottom layer of our column are, the lifting of the column above the layer by the expansion of the layer, and the increase of the difference of temperature between the bottom layer and the next above it; in other words, as $d\,p$ is unchanged, the increase of the $\frac{d\,t}{d\,p}$ subsisting between the two layers. This goes on, as the addition of heat continues, till $d\,t$, the excess of the temperature of the bottom layer above that of the next higher layer, is equal to the expression (4), when the two layers are in neutral equilibrium, and any further addition of heat to the bottom layer will produce unstable equilibrium, and cause the two layers to exchange places. For in this latter state, notwithstanding the greater density of the bottom layer in its original position, the least disturbance raises a portion to a level where, whilst its pressure is the same, its temperature is higher than the portions of the upper layer on the same level, and simultaneously the disturbed part of the upper layer has gone down to a level where, its pressure being the same, its temperature is lower than the portions of the lower layer at the same level; thus the disturbance will be exaggerated by the further rising of the disturbed part of the lower layer, by reason of its relatively small density, and by the further falling of the disturbed part of the upper layer by reason of its relatively high density; and reverse currents are thus formed on opposite sides, and continue till the exchange has been completely effected.

281. In the state of neutral equilibrium we have

$$d\,t = -k_v\,\mathrm{V}\left\{\frac{d\,t}{d\,p} - \frac{t}{p}\right\}d\,p. \tag{5}$$

$$\frac{d\,t}{d\,p}\left\{1 + k_v\,\mathrm{V}\right\} = k_v\,\mathrm{V}\frac{t}{p} \tag{6}$$

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* Expressed in Fahrenheit degrees, and in terms of the volume C and pressure P of a grain of air at temperature 32° the equivalent of this equation is—

$$v = \mathrm{C}\frac{\mathrm{P}}{p}\left\{1 + \frac{\cdot 3665}{180}\,(\tau - 32)\right\} = \frac{\cdot 3665}{180}\cdot\frac{\mathrm{CP}}{p}\left\{\frac{180}{\cdot 3665} + (\tau - 32)\right\} = \frac{\mathrm{C\,P}}{491\cdot 1\,p}\left\{(491\cdot 1 - 32) + \tau\right\} = \frac{\mathrm{C\,P}}{491\cdot 1\,p}\left\{t\right\} = \mathrm{V}\frac{t}{p} \text{ since } \frac{\mathrm{C\,P}}{491\cdot 1} = \mathrm{V}$$

(See definition of V given above.)

Adding a further infinitesimal quantity of heat at the bottom, the two layers at once turn topsy-turvy, the effect of which is to leave the layer which was before uppermost, in the lower position, and with the temperature which the other had in the same position before the receipt of its last increment of heat, and similarly to leave the other layer in the upper position with the same temperature as the originally upper layer *plus* the last increment of heat; and thus the value of $\frac{dt}{dp}$ is reduced: the next increment of heat restores $\frac{dt}{dp}$ to the value shown by equation (5); and these processes, of adding an infinitesimal quantity of heat at the bottom, transferring it with its grain of air to the upper position, and adding more heat to restore $\frac{dt}{dp}$, go on until the difference of temperature between the second and third layers is that shown by equation (5), when for t and p are put the values of them due to the height of the second layer. We have now got the three bottom layers following the law of variation of temperature with variation of barometric pressure involved in equation (5). Continuing the addition of heat to the bottom layer, the topsy-turvy movements follow between the first and second layers, and then between the second and third layers, transferring the heat, as gained, by equal infinitesimal instalments to the third layer first, then to the second layer, and lastly to the bottom layer; this process being repeated till the difference between the third and fourth layers is that shown by equation (5). By repetition of these processes the lower part of the column of air is ultimately heated bodily, and made to follow the law of variation of temperature involved in equation (5).

282. The temperature and pressure at the top of this part of the column, and of all the column above it, are unaffected by the successive communications of heat which we have been considering the effect of, but the column has been lifted bodily at each communication of an increment of heat at the bottom. We may observe here that the topsy-turvy movements between layer and layer may not be substituted by progressive currents of any kind, and that convection currents receive no contributions from the semi-rotations now in question.

283. To find the law of variation of temperature that we have spoken of, we have, transposing the members of equation (6),

$$\frac{dt}{t} = \frac{k_v \mathrm{V}}{1 + k_v \mathrm{V}} \frac{dp}{p}, \text{ and integrating} \tag{7}$$

$$\log t = \frac{k_v \mathrm{V}}{1 + k_v \mathrm{V}} \log p, \text{ and taking the definite integral with the lower limits } p = 1 \text{ and } t = \tau, \tag{8}$$

$$\log \frac{t}{\tau} = \frac{k_v \mathrm{V}}{1 + k_v \mathrm{V}} \log p$$

$$\frac{t}{\tau} = p^{\frac{k_v \mathrm{V}}{1 + k_v \mathrm{V}}}$$

$$t = \tau\, p^{\frac{k_v \mathrm{V}}{1 + k_v \mathrm{V}}} = \tau\, p^{\frac{\lambda - 1}{\lambda}} = \tau\, p^{0{\cdot}28977.} \tag{9}$$

A single observation of the temperature corresponding to a particular pressure will afford means of determining the value of the constant τ, and equation (9) will, when this value is inserted in it, be a complete expression of the temperature law holding in the lower part of the column that has been subjected to the topsy-turvy movements described.

284. It will be seen from what has been said, that on a globe of uniform surface temperature surrounded by an atmosphere of air, the nearest approach that is possible to

permanent uniformity of density of the atmosphere at all heights is that condition which exists when the law of variation of temperature with pressure is that which is expressed by equation (9); for if at any height the value of $\frac{dt}{dp}$ exceed only infinitesimally that which is shown by the derived equation (6), topsy-turvy movements at once commence and prevent the increase of $\frac{dt}{dp}$ from becoming of sensible magnitude.

285. If we knew the law of variation of temperature with pressure in our column, before the communication of heat to the bottom layer commenced, we could, by observing the finite increase of temperature of the bottom layer, determine the height to which topsy-turvy movements extended, and the total amount of heat communicated to the air. For the sake of brevity we will in future call the law of variation of temperature represented by equation (9) the "ultimate law," to distinguish it from the law followed in the column before the communication of heat, which law we will call the "normal law."

286. The same considerations which have led us to the ultimate law, as resulting from topsy-turvy movements, lead to it also as resulting from the rapid upward or downward flow of air which, starting with a given pressure at a uniform temperature, is pushed or drawn by mechanical forces external to itself to a place of different pressure; the whole vertical or oblique stream thus moved taking upon itself the ultimate law, as a direct consequence of equation (4), the work done being in this case the only contributory to change of temperature.* So long as no condensation takes place the vertical or oblique circulation of air mixed with vapour results in a similar distribution of temperature, the expression of the law of which differs from equation (9), only in the substitution of the k_v and V of the mixture of air and vapour for those of air. In considering the actual distribution of temperature in the atmosphere, we think there is good ground therefore for forming and testing a hypothesis to the effect that the distribution bears some simple relation to the ultimate law. We try first, of course, the law itself, and find that the rate of change of temperature given by it is much greater than the actual rate. We next try the assumption that the differences of temperature corresponding to infinitesimal differences of pressure bear a constant ratio to the corresponding differences given by the ultimate law. This assumption gives us in lieu of equation (5)—

$$c\,dt = -k_v \mathrm{V}\left\{\frac{dt}{dp} - \frac{t}{p}\right\} dp \qquad (10)$$

$$\frac{dt}{dp}\left\{c + k_v \mathrm{V}\right\} = k_v \mathrm{V}\,\frac{t}{p}$$

$$\frac{dt}{t} = \frac{k_v \mathrm{V}}{c + k_v \mathrm{V}}\,\frac{dp}{p}$$

$$\log t = \frac{k_v \mathrm{V}}{c + k_v \mathrm{V}} \log p$$

$$\log \frac{t}{\tau} = \frac{k_v \mathrm{V}}{c + k_v \mathrm{V}} \log p$$

$$t = \tau\, p^{\frac{k_v \mathrm{V}}{c + k_v \mathrm{V}}} \qquad (11)$$

* Long after the writer had acquired the habit of appealing to the ultimate law as a valuable aid to the clear conception of problems in atmospheric physics, he found that it had, many years ago, been enunciated by Sir William Thomson, who had concluded from it that the distribution of temperature on the earth's atmosphere would be due more largely to the physical actions of the results of which the ultimate law is the expression than to any others.

which differs from the expression for the ultimate law, only in the values of the constants τ and the index of p.

287. In his "Meteorology, 1862," page 32, Herschel gives mean values of the temperature of the air corresponding to different barometric pressures, derived from observations made during ten balloon ascents in England and France.

These mean temperatures, which we shall make use of to test our hypotheses, are as follows:—

TABLE 153.

Barometric Pressure. p	Temperature.	
	Fahrenheit's degrees.	Fahrenheit's degrees $+459{\cdot}1$.
30·5	65·6	524·7
30	65·0	524·1
29	63·6	522·7
28	62·0	521·1
27	60·2	519·3
26	58·2	517·3
25	56·1	515·2
24	53·7	512·8
23	51·0	510·1
22	48·1	507·2
21	44·9	504·0
20	41·4	500·5
19	37·6	496·7
18	33·6	492·7
17	29·1	488·2
16	24·2	483·3
15	19·0	478·1
14	13·2	472·3
13	7·3	466·4

288. We make use of the highest and lowest values of t and p given in this table to determine the constants, and find them to be $\tau = 327{\cdot}27$; $\frac{k_v V}{c + k_v V} = 0{\cdot}13811$. Inserting these values in (11) the equation was then used to calculate the values of t for the other pressures. The results are compared in the following table with observation.

TABLE 154.

Barometric Pressure. p	Temperature.		
	Observed.	Calculated.	Observed *minus* Calculated.
30·5	524·7	524·7	0·0
30·0	524·1	523·5	+0·6
29	522·7	521·1	+1·6
28	521·1	518·5	+2·6
27	519·3	515·9	+3·4
26	517·3	513·3	+4·0
25	515·2	510·5	+4·7
24	512·8	507·6	+5·2
23	510·1	504·6	+5·5
22	507·2	501·5	+5·7
21	504·0	498·3	+5·7
20	500·5	495·0	+5·5
19	496·7	491·5	+5·2
18	492·7	487·8	+4·9
17	488·2	484·0	+4·2
16	483·3	480·0	+3·3
15	478·1	475·7	+2·4
14	472·3	471·2	+1·1
13	466·4	466·4	0·0

289. We observe now, from the differences in the last column, that the variations of t given by the formula are too large at the high pressures, and too small at the low pressures. We next assume therefore that the differences bear, not a constant ratio to the differences of the ultimate law, but the ratio $c\,p^{\alpha}$, where c and α are constants; and for such an assumption we have good reason, apart from the mathematical requirements of the case; for the molecular theory of gases tells us* that an undisturbed atmosphere tends to acquire a uniform temperature at all heights, and the topsy-turvy movements caused by solar radiation upon the ground may be supposed to stop at all heights up to a certain limit, but oftener at a lower than a higher elevation; thus the distribution of temperature in a lower portion of the atmosphere will approach more nearly to the ultimate law than the distribution in a higher portion, and it is fitting therefore that the factor which converts the difference by the ultimate law into the difference by the actual law should be larger at low than at high elevations. We thus obtain instead of equation (5)—

$$c\,p^{\alpha}\,d\,t = -\,k_0 \mathrm{V}\left\{\frac{d\,t}{d\,p} - \frac{t}{p}\right\} d\,p \qquad (12)$$

* See Maxwell's "Theory of Heat," page 300.

$$\frac{dt}{dp}\left\{c\,p^{\alpha}+k_v\mathrm{V}\right\}=k_v\mathrm{V}\frac{t}{p}$$

$$\frac{dt}{t}=\frac{dp}{p}\,\frac{1}{1+\frac{c}{k_v\mathrm{V}}p^{\alpha}}\text{ ; the integral of which is}$$

$$\log t=-\frac{1}{\alpha}\log\frac{1+\frac{c}{k_v\mathrm{V}}p^{\alpha}}{p^{\alpha}}$$

$$t=\tau\left(\frac{1+\frac{c}{k_v\mathrm{V}}p^{\alpha}}{p_{\alpha}}\right)^{-\frac{1}{\alpha}}$$

$$t=\frac{\tau\,p}{\left(1+\frac{c}{k_v\mathrm{V}}p^{\alpha}\right)^{\frac{1}{\alpha}}} \qquad (13)$$

290. When $\alpha = 0$ this becomes the same case as the previous one, but for any positive value of α this formula will tend to rectify the fault that has been mentioned as attaching to equation (13). On trial with the value of α equal to unity, values of the constants τ and $\frac{c}{k_v\mathrm{V}}$ were found, which, when inserted in equation (13), made the values of t given by that equation for different pressures agree with observation with remarkable closeness. It was noticed, however, that the first and last values, for 30·5 inches and 13 inches of pressure, which must have been derived from fewer observations than the rest, departed notably from the line of progression which followed and preceded them; and accordingly, discarding them as observations from which to determine the constants, we found that with the values $\tau = 180{\cdot}46$ and $\frac{c}{k_v\mathrm{V}} = 0{\cdot}31057$ the calculated values of t at all pressures from 30 inches to 14 inches were in agreement with observation, exactly in the average, and with a maximum difference of 0°·6 in any of the 17 individual comparisons.

291. In Table 155 a comparison is made between the mean observed temperatures corresponding to different pressures, and those calculated from the different formulæ that we have referred to, as well as by the rule of a uniform variation, adopted generally in formulæ for calculating heights by means of observed barometric pressures at different elevations.

292. The closeness of the agreement with observation of the formula

$$t=\frac{\tau\,p}{1+\frac{c}{k_v\mathrm{V}}p} \qquad (14)$$

not only renders it abundantly accurate for our purpose of estimating the height above the ground to which, under particular conditions, topsy-turvy movements reach, but extending, as it does, through more than half an atmosphere, it gives some probability to the correctness of the physical considerations on which the form of the equation is based. A still more exact agreement might be obtained for the first 5,000 feet of elevation by calculating special constants for that region; possibly also for the whole range by trying a value of α slightly in excess of unity.

293. Adopting the formula as it stands, we proceed with our estimation, which will be applicable, like the formula, to the conditions of an atmosphere actually experienced in

TABLE 155.

Barometric Pressure. p	TEMPERATURE. Observed. Mean of Ten Balloon Ascents.	Calculated. With Uniform Variation.	Observed *minus* Calculated.	By Formula (9) $t=\tau p^{\frac{k_v V}{c+k_v V}}$, $\tau=327\cdot27$, $\frac{k_v V}{c+k_v V}=0\cdot13811$	Observed *minus* Calculated.	By Formula (14) $t=\frac{\tau p}{1+\frac{c}{k_v V}p}$, $\tau=180\cdot46$, $\frac{c}{k_v V}=0\cdot31057$	Observed *minus* Calculated.
30·5	524·7	524·7	0·0	524·7	0·0		
30	524·1	523·0	+ 1·1	523·5	+0·6	524·7	−0·6
29	522·7	519·7	+ 3·0	521·1	+1·6	523·0	−0·3
28	521·1	516·4	+ 4·7	518·5	+2·6	521·1	0·0
27	519·3	513·0	+ 6·3	515·9	+3·4	519·2	+0·1
26	517·3	509·7	+ 7·6	513·3	+4·0	517·0	+0·3
25	515·2	506·4	+ 8·8	510·5	+4·7	514·7	+0·5
24	512·8	503·0	+ 9·8	507·6	+5·2	512·3	+0·5
23	510·1	499·7	+10·4	504·6	+5·5	509·7	+0·4
22	507·2	496·4	+10·8	501·5	+5·7	506·9	+0·3
21	504·0	493·1	+10·9	498·3	+5·7	503·8	+0·2
20	500·5	489·7	+10·8	495·0	+5·5	500·5	0·0
19	496·7	486·4	+10·3	491·5	+5·2	496·9	−0·2
18	492·7	483·1	+ 9·6	487·8	+4·9	492·9	−0·2
17	488·2	479·7	+ 8·5	484·0	+4·2	488·5	−0·3
16	483·3	476·4	+ 6·9	480·0	+3·3	483·7	−0·4
15	478·1	473·1	+ 5·0	475·7	+2·4	478·4	−0·3
14	472·3	469·7	+ 2·6	471·2	+1·1	472·4	−0·1
13	466·4	466·4	0·0	466·4	0·0		
Mean from 14 to 30.							0·0

Western Europe in the course of the 10 balloon ascents. It has been explained in paragraphs 281–2 that at the limiting pressure which the topsy-turvy movements have reached, the same temperature exists both under the normal and ultimate laws of variation.

If P be the pressure and T the temperature of the bottom layer when the heating commences, P′ and T′ their values when it ceases, we have from equation (9) $T'=\tau\ P'^{\frac{\lambda-1}{\lambda}}$ or $\tau=\frac{T'}{P'^{\frac{\lambda-1}{\lambda}}}$, whence $t=T'\frac{p^{\frac{\lambda-1}{\lambda}}}{P'^{\frac{\lambda-1}{\lambda}}}$; and from the equation (14) of the normal law $T=\tau\frac{P}{1+\frac{c}{k_v V}P}$ or $\tau=\frac{T}{P}\left(1+\frac{c}{k_v V}P\right)$, whence $t=\frac{T}{P}\left(1+\frac{c}{k_v V}P\right)\frac{p}{1+\frac{c}{k_v V}p}$; and equating

the two values of t we have

$$t = \mathrm{T}' \frac{p^{\frac{\lambda-1}{\lambda}}}{\mathrm{P}'^{\frac{\lambda-1}{\lambda}}} = \frac{\mathrm{T}}{\mathrm{P}} \left(1 + \frac{c}{k_v \mathrm{V}} \mathrm{P}\right) \frac{p}{1 + \frac{c}{k_v \mathrm{V}} p} \tag{15}$$

$$\frac{\mathrm{T}'}{\mathrm{T}} \frac{\mathrm{P}}{\mathrm{P}'^{\frac{\lambda-1}{\lambda}}} \frac{1}{1 + \frac{c}{k_v \mathrm{V}}} \mathrm{P} = \frac{p^{\frac{1}{\lambda}}}{1 + \frac{c}{k_v \mathrm{V}} p} \text{ and, if } \mathrm{P}' = \mathrm{P} \text{ (as is the case with our hypothetical column)} \tag{15a}$$

$$\frac{\mathrm{T}'}{\mathrm{T}} \frac{\mathrm{P}^{\frac{1}{\lambda}}}{1 + \frac{c}{k_v \mathrm{V}} \mathrm{P}} = \frac{p^{\frac{1}{\lambda}}}{1 + \frac{c}{k_v \mathrm{V}} p} \tag{16}$$

294. The value of p which satisfies this equation may be found by calculating values of the right-hand member, and constructing a curve with these values as ordinates and the corresponding values of p as abscissæ; the point of the curve whose ordinate is equal to the left-hand member of (16) will have for its abscissa the required value of p, which we may call π, and which may be obtained with any degree of approximation that may be desired by recalculation of the curve near the point that is chosen for the first approximation.

295. To find now the total quantity of heat that has been communicated to the column that intervenes between the pressures P′ and π, we have, for the heat acquired by a layer dp, expressed in degrees of temperature of a grain of air at constant volume—

$$495088 \left\{ \frac{\mathrm{T}'}{\mathrm{P}'^{\frac{\lambda-1}{\lambda}}} p^{\frac{\lambda-1}{\lambda}} - \frac{\mathrm{T}}{\mathrm{P}} \left(1 + \frac{c}{k_v \mathrm{V}} \mathrm{P}\right) \frac{p}{1 + \frac{c}{k_v \mathrm{V}} p} \right\} dp \tag{17}$$

Since when $dp = 1$, the number of grains of air in the layer is 495088.

The integral of this expression is

$$495088 \left[\frac{\lambda}{2\lambda - 1} \frac{\mathrm{T}'}{\mathrm{P}'^{\frac{\lambda-1}{\lambda}}} p^{\frac{2\lambda-1}{\lambda}} - \left(\frac{k_v \mathrm{V}}{c}\right)^2 \frac{\mathrm{T}}{\mathrm{P}} \left(1 + \frac{c}{k_v \mathrm{V}} \mathrm{P}\right) \left\{ \left(1 + \frac{c}{k_v \mathrm{V}} p\right) - \log \left(1 + \frac{c}{k_v \mathrm{V}} p\right) \right\} \right] \tag{18}$$

and the definite integral between the limits P′ and π

$$495088 \left[\frac{\lambda}{2\lambda - 1} \frac{\mathrm{T}}{\mathrm{P}'^{\frac{\lambda-1}{\lambda}}} \left\{ \mathrm{P}'^{\frac{2\lambda-1}{\lambda}} - \pi^{\frac{2\lambda-1}{\lambda}} \right\} - \left(\frac{k_v \mathrm{V}}{c}\right)^2 \frac{\mathrm{T}}{\mathrm{P}} \left(1 + \frac{c}{k_v \mathrm{V}} \mathrm{P}\right) \left\{ \frac{c}{k_v \mathrm{V}} (\mathrm{P}' - \pi) - \log \frac{1 + \frac{c}{k_v \mathrm{V}} \mathrm{P}'}{1 + \frac{c}{k_v \mathrm{V}} \pi} \right\} \right] \tag{19}$$

Inserting now in (15a) and (19) the numerical values of the constants that we have decided to adopt, they become

$$\frac{\mathrm{T}'}{\mathrm{T}} \frac{\mathrm{P}}{\mathrm{P}'^{\cdot 28977}} \frac{1}{1 + \cdot 31057\,\mathrm{P}} = \frac{p^{\frac{1}{1\cdot 408}}}{1 + \cdot 31057\, p}, \text{ and} \tag{20}$$

$$495088 \left[\cdot 77533 \frac{\mathrm{T}'}{\mathrm{P}'^{\cdot 28977}} \left\{ \mathrm{P}'^{1\cdot 28977} - \pi^{1\cdot 28977} \right\} - \left(\frac{1}{\cdot 31057}\right)^2 \frac{\mathrm{T}}{\mathrm{P}} \left(1 + \cdot 31057\,\mathrm{P}\right) \left\{ \cdot 31057\,(\mathrm{P}' - \pi) - \log \frac{1 + \cdot 31057\,\mathrm{P}'}{1 + \cdot 31057\,\pi} \right\} \right] \tag{21}$$

For an example let us take P = 30, for which the formula (14) gives T = 524·735; also let P′ = 30, and T′ = 534·735.

Equation (20) then becomes

$$\frac{534 \cdot 735}{524 \cdot 735} \frac{30}{30^{\cdot 28977}} \frac{1}{1 + \cdot 31057 \times 30} = \frac{p^{\frac{1}{1\cdot 408}}}{1 + \cdot 31057\, p} \tag{22}$$

whence $\pi = 27 \cdot 122$, and (21) is then

$$495088 \left[\cdot 77533 \frac{534 \cdot 735}{30^{\cdot 28977}} \left\{ 30^{1\cdot 28977} - 27 \cdot 122^{1\cdot 28977} \right\} - \frac{1}{(\cdot 31057)^2} \frac{524 \cdot 735}{30} (1 + \cdot 31057 \times 30) \left\{ \cdot 31057\,(30 - 27 \cdot 122) - \frac{1}{\cdot 4343} \log_{10} \frac{1 + \cdot 31057 \times 30}{1 + \cdot 31057 \times 27 \cdot 122} \right\} \right] = 7749100 \tag{23}$$

or the quantity of heat communicated to the lower part of the column is 7749100 times the quantity required to raise one degree the temperature of a grain of air at constant volume. Dividing this by the difference between the bottom and top pressures (2·878), and by 495088, we get for the average increase of the temperature of the heated part of the column 5°·4135, equal masses of air having equal weights in determining the average.

296. As the proportion of that portion of each infinitesimal increment of heat consumed in producing simple increase of temperature is to that portion which does work in expansion as 1 to $\lambda - 1$, or as 1 to 0·408, so the total quantity of heat will be to the total increase of temperature, irrespective of work done, as 1·408 to 1; hence the total quantity of heat communicated to the bottom of the column is

$$7749100 \times 1{\cdot}408 = 10910700°. \qquad (24)$$

Lateral Currents.

297. Let us now modify the circumstances of our column, so that the columns to the left of it receive increments of heat of less and less amount as they recede from the reference column; the lower parts of the columns will thus acquire unequal temperatures at equal heights, and we shall have a lateral variation of temperature, the effect of which we will consider later, confining our attention, for the present, to the modification which must be made in the account which we have given of what occurs when the conditions are uniform all round. A small portion of the work of expansion which before was effective altogether upward is now effective to push the lowest stratum of air towards the left, and the lateral velocity of this stratum and (by means of friction) the velocities of the strata near and above it towards the left will increase so long as the right-hand columns receive more heat in the same time than the left-hand columns.

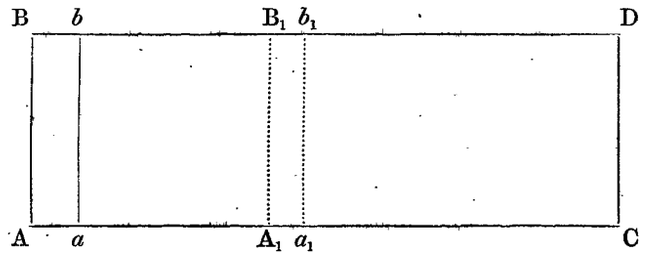
We find reason for suspecting that such a motion is generated and becomes sensible under suitable conditions in the bottom stratum of the earth's atmosphere. In the case of the trial column that we have already considered we found that to produce an increase of 10° in the temperature of the bottom layer the addition is requisite of 10910700° of heat of a grain of air at constant volume. The work which this amount of heat does is $\frac{\lambda - 1}{\lambda} \times 10910700 = 3{,}161{,}600$, and this is the work done by an average increase of 5°·4135 in a column of air about half a mile high. If we suppose a series of columns reaching 6,000 miles round the earth's equator, with an average increase of 2°·7 in the temperature of the lower portion of the whole 6,000 miles of air, and that all the work of expansion is expended laterally, we get a total lateral expansion of 32 miles, and attributing this to six hours of time, we have an average velocity of about 2·7 miles per hour. Now much the greater part of the work being expended in upward expansion, this velocity is much greater than can, with any reason, be attributed to the mass of air included in the height of an average column, but it may not be greater than the smaller amount of work would produce on a small mass of air near the bottom of the slice. In fact we shall see later that both at Poona and Belgaum there is a motion of the surface air away from the heated soil in the interior of India in the daytime, and towards the same soil when cooling at night; a motion contrary in great measure to the motions which have place during the same hours, under the land and sea breeze theory. Another circumstance that would give rise to a reinforcement

of this motion is, that when a column of air is lifted by the expansion of the bottom of it every layer of it is forced up to a position of smaller barometric pressure than the position which it leaves; and it therefore pushes away from it the layer on its own level of a column which has been less lifted than the one in which it lies; hence there is a general pushing out, from top to bottom of the columns, from a place of more rapid lifting of the air to a place of less rapid lifting.

298. It need only be mentioned, to gain assent, that the difference of rate of cooling, on the side of the earth's atmosphere, the bottom layer of which is cooling, will give rise to a continuation of the surface motions caused by a reverse mode of operation on the side which is being heated; and similarly with regard to the falling of each column, which follows upon the cooling of its bottom strata. Thus the surface winds will receive increments of velocity between the place of most rapid heating and the place of most rapid cooling, and directed from the former to the latter.

299. Let us now turn our attention to a horizontal channel of air, one square foot in section, and under varying pressures and temperatures as we proceed along the tube.

FIG. A.



If the point A in Fig. A be taken as the origin of x, and x be measured towards the right of A, we may suppose the pressure (p) and temperature (t) expressed as known functions of x, (say)—

$$p = f(x)$$
$$t = \varphi(x)$$

from which

$$\frac{dp}{dx} = f'(x)$$
$$\frac{dt}{dx} = \varphi'(x)$$

and

$$\frac{dt}{dp} = \frac{\frac{dt}{dx}}{\frac{dp}{dx}} = \frac{\varphi'(x)}{f'(x)} \qquad (25)$$

300. In applying equation (4) to this case, we may therefore regard $\frac{dt}{dp}$ as known. If now the slice of the channel A B b a—supposed to contain one grain of air—move from its position of pressure p and temperature t to the position of A_1 B_1 b_1 a_1 of pressure $p + dp$ and temperature $t + dt$, the heat developed in it, by the work done upon it, will by equation (4) be

$$-k_0 V \left\{\frac{dt}{dp} - \frac{t}{p}\right\} dp$$

and its abnormal heat, if retained, in the new position would be

$$-k_0 V \left\{\frac{dt}{dp} - \frac{t}{p}\right\} dp - dt \qquad (26)$$

a quantity which will only rise to an important magnitude when the rate of change of pressure along the tube is rapid; for instance, in the practical case of air streaming towards the centre of a cyclone.

301. The moving force due to variation of pressure with variation of x being

$$-495088\, g \frac{dp}{dx} dx,$$

and the mass moved, when the section of the channel is one square foot, being

$$\frac{dx\, p}{V\, t},$$

the acceleration will be

$$\frac{dv}{d\tau} = -495088\, g\, V \frac{t}{p} \frac{dp}{dx} \qquad (27)$$

302. And such acceleration, when existing at any one height, will exist, and will have the same sign, at all heights of the same column; for slight abnormalities of barometric pressure at different heights find a ready relief by vertical motions and quickly disappear; consequently a difference of lateral pressure produces a bodily motion of an air atmosphere from top to bottom, and not circulating currents. That persistent abnormalities of pressure of sensible amount in different parts of a vertical column of air are impossible may be thus shown. Suppose a column of one square foot of horizontal section and of 30 inches of pressure at the bottom, and, if possible, let the upward pressure one foot from the bottom be ·001 inch greater than the weight of air in the column above that height. There will then be an upward acceleration upon the column above the height of one foot equal to $\frac{\cdot 001}{30} g = \frac{g}{30{,}000}$; but as it will at once begin to diminish let us take it at $\frac{g}{60{,}000}$ only. In $\frac{2}{\sqrt{g}}$ seconds the column will (by the formula $s = \frac{1}{2} f t^2$) have been lifted $\frac{1}{30{,}000}$ foot, and the cubic foot of air at the bottom having expanded at the same time, its excess elasticity will already, in $\frac{2}{\sqrt{g}}$ seconds, have to a large extent disappeared; and the same thing follows, if we suppose the ·001 inch of excess pressure to be distributed in infinitesimal equal portions at points which divide the column into pressures in arithmetical progression; for the acceleration on each portion of the column is the same, $\frac{g}{30{,}000}$, as the acceleration was before on the whole column.

Convection Currents.

303. In introducing his account of the trade winds, Herschel writes as follows:—*

"We have seen that the immediate effect of the application of heat to any region is to "generate an ascensional movement in the incumbent atmosphere, a bodily overflowing of "its material above, and a relief of barometrical pressure below. The air of the cooler "surrounding region not being so relieved (but rather the contrary, owing to the increase "of weight poured on it from above), will be driven in by the difference of hydrostatic "pressures so arising, and thus originate two distinct winds, an upper one setting *outward* "from the heated region, a lower *inward*. If the region heated be a limited one, these "currents will radiate from and to it as a centre; if a linear tract, or a whole zone of the "globe, such as the generally heated intertropical region, they will assume the character

* "Meteorology," page 56.

" of two sheets of air, setting inwards on both sides below, uniting and flowing vertically " upwards along the medial line, and again separating aloft, and taking on a reversed " movement." He then proceeds to explain the effect of the earth's rotation in modifying the north and south directions of the trades and anti-trades.

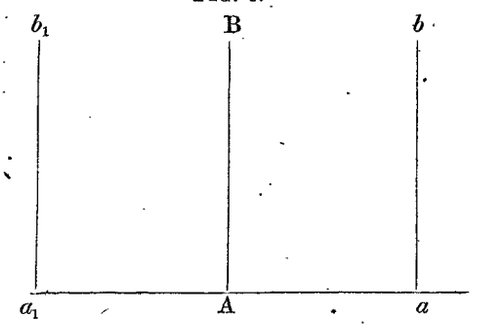
304. We shall have frequent occasion to call attention to exemplifications of the relations here described by Herschel, as subsisting between the ground surface winds and lateral variations of temperature; but, in doing so, we shall distinguish that part of the theory which is general from that which applies specially to the trade-winds, by calling the former the *convection current theory*.

Various Motions to which the Air in a vertical slice of an Atmosphere is subject.

305. We are now prepared to consider the motions in a vertical slice of an atmosphere.

Let A B (Fig. c) be the place where equal increments of temperature are being most rapidly received: besides the topsy-turvy movements that we have described in paragraphs 280 to 284, and that occur everywhere on both sides of A B where the temperature is rising in the bottom layer, but most vigorously near A B, work will be done in pushing outward from A B, and laterally on both sides, the bottom stratum of the atmosphere, and equivalent velocities will be generated in the several elements of that stratum as we recede from A B, until we reach, on either side, a place of minimum rate of heating, or maximum rate of cooling. The former movements will give rise to the kind of agitation that is sometimes visible when an extensive sandy soil is being heated by the midday sun; and the latter action will result in surface winds which receive accelerations in the direction right to left between A B and the place of minimum rate of increase to the left of it, and reverse accelerations on the right of A B.

FIG. c.



306. Next let $a\ b$ represent the place of maximum temperature, and $a_1\ b_1$ the place of minimum temperature of the bottom layer. At $a\ b$ the heating of the lower part of the column due to topsy-turvy movements will have reached to the greatest height; and this height will gradually decrease towards $a_1\ b_1$, where it becomes nothing. The rate of variation of temperature with height will approach most nearly to the ultimate law at $a\ b$, and be slowest at $a_1\ b_1$.

307. An observed case of such a difference of rate in regard to the diurnal heating and cooling is given by Dr. Helmann in a discussion of observations made in May 1872 by the United States War Department at the summit (1,915 metres high) and at the base of Mount Washington, New Hampshire. He finds that between 4 and 5 p.m. the rate of decrease of temperature per 100 metres of height is 0°·83 centigrade, whilst at 6 a.m. the rate is only 0°·48 c. ["Nature," Vol. 13, page 97.]

308. To the right of $a\ b$, and between it and a place of minimum temperature on that side, the temperature of the bottom layer is falling, for the increments of heat which have

been positive between a_1 b_1 and a b are now negative: the effect of this is to condense that layer, and, by conduction of heat from above, a few layers above it; but as the conducting power of air is very low, but little heat would be abstracted in this way from the upper atmosphere—supposed in a condition of stillness. If, however, the atmosphere be in a state of agitation, as is the earth's atmosphere, mixture will take place from layer to layer of air, and the excess heat of lower layers will be gradually transferred, by conduction, through the perpetually changing surfaces of contact, to upper layers; a process which must be supposed to remove to the upper atmosphere in the course of a full period—to be there similarly transferred upward, and ultimately thrown off into space—nearly the whole of the heat gained by the lower atmosphere, by means of topsy-turvy movements, during that portion of the period when the receipts of heat by the bottom layer of the atmosphere exceed the expenditure by radiation or otherwise. [We are here proceeding on the assumption that the radiating power of dry air is insignificant, and that radiation from vapour or cloud in the air is too small to accomplish the removal of the large quantity of heat in question.]

309. Convection currents will flow in the lower region from a_1 towards a, upwards in the neighbourhood of a b, from b towards b_1 in the upper region, and downwards in the neighbourhood of a_1 b_1; and it is evident that, as the lateral variations of temperature are of smaller range as we ascend from the ground level a_1 a to higher levels, so the strength of the circulating convection currents that are passed through in the ascent will, up to a certain limit, become feebler.

Consequences of Physical Notions put forward.

310. Under the guidance of the physical notions that we have now put forward, let us, before appealing to observation for confirmation of them, summarize the effects that should be expected to be observable in the earth's atmosphere, and especially in the part of it overlying India, with which we have immediately to do.

First, then, wherever the layer of air in contact with the ground is receiving heat from the soil, we expect that the topsy-turvy movements which we have described in paragraphs 280 to 284 convey the heat upward to a limited height, and heat the whole of the column of air below that height, leaving it in a condition of which the "ultimate law" of variation of temperature with pressure is a characteristic;* that—the normal law being the same—

* Since these views became familiar to the writer, he has had the opportunity of witnessing from the heights of Simla (in the months September to November of the year 1874) a phenomenon which struck him as being significantly related to them. Towards sunset there appears on the eastern horizon, and evidently overlying the plains beyond the foot of the Himalayas, a thick haze which has a clearly defined and nearly horizontal upper boundary line separating it from the relatively clear atmosphere above. Can it be that this haze consists of particles of dust, of smoke, and of other impurities, carried upward by the topsy-turvy movements described, and does the well defined and nearly level outline imply only that the height to which the upward movements reach is nearly the same over the surface of the plains generally? and if so, have we not here the means, by observing from elevated stations the altitude of the haze-line, of determining the limiting height of the normal upward movements?

We observe also that in a paper in the "Philosophical Transactions," Vol. 165, Part I., page 159, Mr. J. B. N. Hennessey, F.R.S., speaks of this haze as an autumn phenomenon, that he had noticed year after year, and which grows day by day in height, until it attains to perhaps 3° or more above the horizon; it grows, moreover, denser daily, until at last it is sufficiently opaque to obscure the sun's rays. A similar haze, but generally with less strongly marked upper limiting line, is a common phenomenon overlying the plains of the Konkan between Bombay and the Western Ghauts. The dust haze of the Germans may also be generally due to the same cause.

the height reached after a given time is greatest where the total quantity of heat received at the ground surface is greatest; that the perpetual agitation of the atmosphere causes a transfer of this heat upwards by conduction, which is rapid in comparison with that which would follow in an absolutely still atmosphere, and which, in respect of periodical variations, restores the normal condition in the lower atmosphere—that is, transfers upward nearly as much heat as has been received—in the course of a full period; that the topsy-turvy movements, which result from the relative greater buoyancy of layers of air *when disturbed* as compared with higher layers, cannot be substituted by currents of any kind, and do not contribute directly to the convection currents which actually flow in the earth's atmosphere.

311. Secondly, of the heat received by the ground surface layer, a proportion, equal to $\frac{\lambda - 1}{\lambda} = 0{\cdot}28977$, is consumed in doing work by expansion, principally in lifting the atmosphere above it, but, when there is a lateral difference in the rate of heating, also by pushing the lowest stratum of air away from the place of most rapid heating. In the last case the surface wind should receive increments of velocity directed from the place of most rapid heating towards the place of most rapid cooling.

312. Thirdly, lateral variations of barometric pressure produce bodily motion from top to bottom of the atmosphere, which motion receives increments of velocity between places of high and low pressure, directed from the former to the latter.*

313. Fourthly, systems of circulating convection currents will exist by reason of lateral difference of temperature of the air, producing surface winds blowing—though not generally directly—from the place of least temperature of the air towards the place of greatest temperature; and similar subordinate systems will exist, over and above the principal ones, in localities where there is an abnormal lateral variation of the temperature of the air.

General Course of the Thermal Equator.

314. It will help us to a better understanding of the relations holding between the wind systems and temperature distribution of our comparatively limited region if, in the first place, we acquaint ourselves with the general course of the thermal equator in different seasons, as exhibited by the Messieurs Schlagintweit in the maps of their "India and High Asia, Atlas, Part IV."

In the map for the quarter June to August the thermal equator enters the Karnatik in about longitude 79°, with a temperature of 85°; proceeds due north to the Ganges valley, which it skirts, with a temperature of 88°; and turning north-westward it passes through the Punjab, with a temperature of 92°; thence—consulting our own maps—it will be seen that it ought to turn south-westward, passing through Upper Sind, with a temperature of 96°. The general course of the winds shown in our maps for these months is towards, and approximately at right angles to, the track of the thermal equator.

[* With this question the writer proposes to deal in a supplementary paper.]

315. In the quarter September to November the thermal equator still enters India in the Karnatik, but proceeding north-north-westward through Maisur, it then turns west-north-westward towards the Western Ghauts, and afterwards north-westward towards the coast of Kattywar, which it crosses, and then it skirts the sea coast beyond. During the month of October our map shows winds in the region where the thermal equator crosses the Bombay Presidency of no decided persistency; and northward of the line there is during the quarter a gradual change of the winds from being directed towards the thermal equator of the previous quarter, to holding the same relation to the changed course of that line.

316. In the quarter December to February the thermal equator has passed wholly to the south of India, and the winds are such as, modified by local conditions that will be spoken of later, are conformable to the trade-wind theory.

317. For the quarter March to May the thermal equator enters the south of India about longitude 78°, proceeds nearly due north to Central India, which is a region of maximum temperature (90°), and then, turning westward, passes through Southern Malwa, Guzerat, and Kutch. The winds of our map for March, being undecided where the thermal equator crosses, are in accordance with the notion of the latter being a place of meeting of contrary winds; but the winds of April and May decidedly require that the westward bend of the thermal equator for these months should be further north, the west and south-west winds of Guzerat and Malwa having already a large preponderancy; indeed the winds of May require but little change to transform them to the type of the rainy quarter June to August.

Sketch of the theoretical relations of various Phenomena.

318. We proceed now to give a brief sketch of the theoretical relations of the distribution and variations of temperature, of the distribution and variations of rainfall, and of the wind system of the Bombay Presidency, which seem to us best to accord with the data at our disposal.

319. Considering the decrease of temperature from the equator northwards, and from the equator southwards, it is obvious that convection currents rising in the heated region, and descending in the cool, will flow on the earth's surface from the cool to the hot region, and aloft in the reverse direction, the direction being modified in both cases by the earth's rotation; and the medial line towards which the surface winds of the two hemispheres tend will move northward and southward as the sun goes northward or southward in declination, and will deviate from the east and west direction wherever, as in India, solar radiation on the soil of a large tract of land causes the thermal equator to run partly or wholly in a north and south direction. Indeed, whatever be its direction, we may regard the thermal equator as marking out the medial line towards which the winds on opposite sides of it tend. At any point of the course of these winds other circumstances, besides the direct tendency to the medial line, will operate to determine directions of motion not always at right angles to the nearest part of that line. First, we may mention a pre-existing motion with which the air reaches the sphere in which Indian or continental influences are the preponderating ones; secondly, that the directions of the isothermal lines, near the place considered, which may

not be parallel to the nearest part of the thermal equator, are the directions across which the forces then acting tend to make the convection currents of the place flow; and, lastly, that, as in the case of the quarter June to August, the thermal equator may itself have a variation of temperature along its length, in which case the winds from both sides would tend towards the direction in which the heat increased.

320. In the motion of the air towards the medial line the accelerations which it receives on its way will vary with the closeness of consecutive isothermal lines; and these we notice are, in the hot quarter, March to May, thickly crowded together near the western border of the peninsula, whilst the interior and elevated region on each side of the thermal equator has a nearly uniform temperature. Also, we may assert that, whenever the isothermal lines protrude abnormally into regions through which the general course of higher or lower isothermals lies, abnormal accelerations will be received by the surface convection currents directed across the abnormal isothermal lines; and these accelerations, in instances that we shall draw attention to, accumulate to such a magnitude as to obscure the otherwise normal wind of the district.

321. We adopt then those consequences of the trade-wind theory, which give circulating currents ascending at the equator, and with north-east surface winds at some distance north of the equator, and south-east surface winds at some distance south of the equator, and with intervening calms, also with upper currents respectively in a south-west and north-west direction. Further, we regard as well established the facts that the thermal equator travels northward and southward with the sun, and that during the northern summer it lies as far north, or nearly, as the border of the Asiatic continent; that in consequence the air moved towards it from the south, across the geographical equator, has a westerly velocity component due to the earth's rotation; and that hence come the south-west monsoons of the Indian seas which prevail at this season, and that would prevail over the peninsula were it not for the powerful local influences which there alter or subvert its character. The north-east monsoons of the winter season we regard similarly as the simple trade-wind, modified or otherwise according as it is found over the land or over the ocean; and we shall have to point to modifications which—ordinary preconceptions notwithstanding—are as great in this season as those of the south-west monsoon in its season. After having shown that, on the basis now laid down, the observed winds of the Presidency admit generally of being referred in a simple manner to the contemporaneous temperature distribution, we shall be able, knowing something of the previous course of the winds which bring rain, to show that—given a current of moist quality—it depends more largely upon the upward movement of the current than upon any other circumstance whether or not the vapour will be largely condensed and thrown down as rain; and this dependence will be traced in considerable detail as the surface currents flow upward or downward in their progress across the country.

Distribution and Variation of Temperature.—Comparison of Fact with Theory.

322. The following conditions are all largely influential in determining the temperature distributions and variations with which we are immediately concerned; and evidences of this

we will now set forth in some detail, omitting, however, those which have been dwelt upon in preceding pages. The conditions are these:—

I. The sun's declination, or, in other words, the season of the year.
II. Proximity of the sea.
III. Elevation of the place and contour of the country; and
IV. The prevalent winds, and particularly the monsoon winds and rain.

To these would generally have to be added "the latitude of the place," but, owing partly to the superior absorbing power for the sun's heat of the land as compared with the ocean, and partly to the unequal influence in different latitudes of the other conditions named, there is, on the average of the year, scarcely any variation of temperature attributable to difference of latitude within our boundaries. Consulting our mean annual temperature map (Plate LXVII.), we observe the influence of the sea most distinctly in the equable temperature of the coast of the Konkan, and in the relative coolness of the coast of Sind and Kutch as compared with the interior of Sind; and it is doubtless because the influences of elevation and of the monsoon cloak the same temperature relation of the coast to the interior from the Konkan eastward that it is not as well exhibited in the latter region as in Sind. It is strongly marked, however, in the map of annual ranges (Plate LXVIII.) in the small ranges of the Konkan coast as compared with the ranges in corresponding latitudes in the Deccan, and also in the same relation of the ranges of the coast and interior of Sind. The effect of difference of elevation of the general ground surface, as distinguished from that of solitary hills or ridges, is least mixed up with other influences on the Deccan; there we have, on the same map (Plate LXVII.), in the south, a group of stations crossing the river courses at some distance from their sources, showing an average temperature of 80°·8, whilst nearer the Ghauts, and therefore nearer the sources of the rivers, and higher up, we have temperatures ranging between 73°·6 and 77°·4; and again, in the north, there are groups running nearly athwart the river courses, near the sources, and further down the rivers respectively, showing mean temperatures of 77°·4 and 79°·4. As examples of stations on solitary hills or ridges may be mentioned Purandhar and Punchgani, which have nearly the same height, and have mean annual temperatures of 69°·7 and 69°·1; and Mahableshwar, which is about 400 feet higher, with a temperature of 67°·3. The temperature of Matheran, which may be compared with that of Bombay (79°·2) is 73°·0; that of Mount Abu (68°·5) may be contrasted with that of Deesa (79°·8). It will be observed that the group of stations in the south of the Deccan, although from 1,500 to 2,000 feet or more above the sea level, has about the same mean temperature as the stations in the Southern Konkan, which are but little raised above the sea; a fact which is in agreement with the remark already made, that here, as in Sind, the temperature, after allowance for elevation, increases as we proceed inland. This is doubtless in consequence partly of the superior absorbing power of the land as compared with the sea, and partly of the fact that winds from seaward, which keep the coast cool, are gradually heated in their progress over land. We see from this how utterly misleading must be corrections of observed temperatures to mean sea-level, which are based on the assumption of a uniform rate of decrease with height, and this may be quoted as an example of the kind of reasons which have led us to prefer the exhibition of simple averages of the phenomena observed, rather than to apply arbitrary corrections, the constants for which would have at the present stage of inquiry to be rather guessed at than determined. We have, however, in our discussion of the annual variations of temperature (paragraphs 234–5) pointed out the way in

which the influences of the seasons and of the monsoon may be eliminated, and the problem of allotting numerical values to the other effective influences be thus simplified.*

Comparison of Wind Systems and Temperature Distributions of different Seasons.

323. We will now ask the reader to return to paragraphs 242 to 253, where we have given a sketch of the wind systems of the Presidency, and compare the general statements made with the contemporaneous temperature distributions exhibited by the maps of the several months. With regard to the winds of the low region, but exclusive of Sind, during the monsoon months, June to September, we need only add to the remark already made that they blow generally towards the thermal equator, the further one, that over the Konkan they retain more of the south component which they possess over the sea to westward than do the winds of the Deccan; and these latter have more of the same character on the western border than further eastward, where the tendency toward the thermal equator has a greater preponderance. In Upper Sind, as we have already pointed out, the thermal equator runs north-east and south-west, and the winds of Lower Sind we have seen gradually turn so as to blow in Upper Sind athwart the course of the isothermals. The winds of Rohri seem to indicate that even in this season the place lies on the northern side of the thermal equator. During the winter months cold isothermals project from Upper Sind towards Guzerat, and then (proceeding southward) resume the normal east and west direction of the season; consequently we have, in accordance with the convection current theory, winds of which the principal component is directed from the cold region across the direction of the isothermals. These winds in Upper Sind are already in October and November from north and north-west, and in Guzerat and the Konkan from December to February mainly from the north; except to southward of Bombay they have great persistency, but this becomes less as we proceed southward, and at Goa has almost disappeared.

324. In the progression from winter to summer we have near the sea coast a growing west component of the wind, a persistent sea breeze, due to a growing excess of the temperature of the border of the peninsula over that of the sea bordering the coast; the advance northward of the thermal equator also gives rise to a growing west component over the sea, and therefore to the air when it reaches the coast; and the thermal equator having in the quarter March to May become a north and south line crossing the peninsula as far northward as the Nerbudda valley, we have further accessions of wind from westward, due to the tendency of the air to move towards that line. Inland the first two of these contributories to a west component gradually expend themselves, and the west wind that remains is principally attributable to the last-mentioned condition, and is accordingly, and because the isothermals are widely separated, less persistent than near the coast. In Guzerat and Malwa, however, the tendency of the air towards the thermal equator is powerful, and the persistencies of the winds comparable with those on the coast, notwithstanding the distance of the stations from the sea. In this way we think the large

* That we have, notwithstanding the reductions to mean sea level, made use of the isothermal charts of the Messieurs Schlagintweit to learn the general course of the thermal equator in different seasons, we may explain, is because those charts are not open to the objection made in the text, the corrections adopted varying both with the season and with the height.

duration coefficients of the winds that prevail in the low region from Dápoli to Tando Aláhyar between winter and summer receive a sufficient explanation. On the other hand, when the return movement of the winds from the summer to the winter character is in most rapid progression, the north-east monsoon, or trade-wind, has a prevalence of considerable firmness; and the west component of this period is consequently less than during the winter to summer movement.

325. That the direction of principal change, which from Tando Aláhyar to Dápoli in the low region is nearer to north than to west, differs so considerably from that of the Deccan, which is but slightly north of west, is in accordance not only with the fact that the direction of the thermal equator shows a corresponding difference over the Deccan and in its course further north, but with the fact of the large increase of temperature from south to north in the low region generally during the monsoon months, and the large decrease during the winter months; the latter conditions giving rise to an annual variation of the wind having a north and south direction of principal change; and our temperature maps tell us that in the Deccan there is no variation of temperature in a north and south direction of comparable magnitude with that of the low region, and the maps of most months show no distinct sign of such a variation of any magnitude.

326. The remarkable fact that the monsoon winds of Malwa, as well as those of other seasons, are, both on the northern and southern edges, deflected towards the interior of the plateau, we explain on the same general convection current theory to which in the main are referred the trade-winds and land and sea breezes. The air over the lower plateau of the Deccan, and over the low region lying to the north-west and running parallel with the Aravalli mountains, and adjoining and on the same level with the Malwa plateau, must be of lower temperature than the air over the borders of the latter plateau itself; hence convection currents will flow towards the plateau at its surface and edges, and outward aloft. Similarly the mean annual temperature of the air over the peninsula at large must be higher than the mean annual temperature over the surrounding seas—since these are tropical seas—at corresponding heights; and consequently, with the exception of only one of our full-year stations, we find the prevalent winds of the year blowing always from the ocean towards the interior. That the mean temperature of the air over land is greater than that of the air over sea, has been shown by an investigation of Professor Dove to be highly probable as a general fact affecting the whole globe, for he has shown that the mean temperature of the northern hemisphere, which has a surface mainly of land, is considerably greater than the mean temperature of the southern hemisphere, the surface of which is mainly covered by the ocean.

Besides, the ground surface may be regarded as the immediate source of the heat by which the atmosphere is warmed; and as the elevation of the surface is rather a reason for its being hotter than cooler than low ground, the heights of equal temperature ought to be heights above the ground surface rather than heights above sea level, were it not that intercommunication laterally between the atmosphere overlying high ground and that overlying low ground tends to equalize the temperature at equal heights above the sea level. It is clear, nevertheless, that on the whole an excess of temperature will remain over the elevated ground. In accordance with this, Mr. Herman de Schlagintweit finds, in his

discussion of the meteorology of India, that the rate of decrease of temperature with increase of height is more rapid when the elevated station is a peak or a ridge than when it is an extended plateau;* and the rate is generally much smaller on the slopes of mountains than that which has been found for corresponding heights in the free air by Mr. Glaisher and other aeronautical observers; and the last remark is not altogether vitiated by great differences in the geographical situation of the places to which the observations have reference. And, again, in accord is the fact that the annual isothermals have a northward inflexion in passing across the Indian Peninsula, which implies that the interior of the peninsula, which is generally elevated, is warmer at corresponding latitudes and heights than the coasts, which are bordered by low land, of the seas which surround it; but as the low lands are also kept cool by being near the sea, the inference in this case must combine the condition of such nearness with that of depression of the general ground surface.

327. Not only does the wind blow, on the average of the year, generally towards the interior of the peninsula, but as the convection current theory requires, it is more persistent on the coast than some distance inland, and more persistent on the low plains of the Konkan than at the hill stations, either Matheran or those of the Deccan; and as the theoretical currents are strongest near the ground surface (see 309), it is consistent with the theory that the local abnormalities of the Indian Peninsula should in some degree give place at elevated stations to the general course of the trade-winds over the southern border of Asia and the adjoining seas; and thus we find the direction of the monsoon wind to be at the hill stations decidedly south-west, whilst on the Deccan generally it is nearly west, with but a small south component. For the same reason, viz., that the surface convection currents of local origin grow weaker as we ascend and as we proceed inland (see 320), the easterly winds of the north-east monsoon are felt first at the hill stations, and later on the coast; they have also a greater preponderance and appear earlier on the Deccan than on the coast.† That they are felt later in Malwa than in Guzerat is doubtless due to the westerly wind components blowing inward on the western edge of the plateau, from which our stations are not far removed.

328. Though we cannot say conclusively that, because the wind duration coefficients of the year are smaller for the Deccan than for the Konkan, therefore less air is carried across the country, yet, in the absence of observations of velocity of the wind, it is allowable, where great differences exist, to assume as probable that the inference is correct. Adopting it, we are driven to the conclusion that part of the air which flows eastward on the coast of the Konkan must find an outlet by some other route than a continued movement along the ground surface towards the interior of the peninsula. We might suppose that the area of the vertical section of the flowing current was greater, in larger degree than the inverse proportion of the densities of the air, in the Deccan than in the Konkan; but we prefer the

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* "India and High Asia," Vol. IV., page 138.

† As an instance of this, we may again refer to the remarkable fact that the average east duration coefficient of Goa for the months November to May (even) is about 1·0 less than that of Belgaum.

alternative supposition that much of the eastward motion observed in the Konkan is part of a local system of convection currents, which ascend before reaching the Western Ghauts, and either return westward aloft without passing over the surface of the Deccan at all, or destroy existing easterly motion in upper currents that do pass onward. We have reasons for believing that the land and sea breezes of the Konkan form part of such a local system, having a diurnal period; and we only add to this a persistent system of the same kind, in the supposition that we have just made. One of the reasons that we allude to is that such diurnal variation of the wind as there is on the Deccan,—and it is of considerable magnitude at Belgaum—is of a radically different, and in great measure contrary, character to the land and sea breeze variation, and that therefore the surface winds imply a limitation of the sphere of operation of the land and sea breezes somewhere to the west of our two stations Poona and Belgaum. Another reason is afforded by the observed decrease of temperature between the Konkan and the Deccan, which is small during the winter months and relatively large during the monsoon. We shall shortly show (paragraphs 364–5) that if a continuous current of air flowed eastward over the surface of the Konkan and Deccan, being necessarily lifted up to the plateau on its way, it would lose temperature by reason of the work done by it in expanding to an extent much exceeding the observed differences of temperature in either season; and whilst we can assign a satisfactory explanation, in the latent heat liberated in the condensation of vapour, for this being so during the monsoon, when there is no doubt that the winds of the Konkan continue without interruption over the Ghauts, we can only account for the small difference during the part of the dry season when westerly winds prevail by supposing that the air does not really rise from the low level or does so only in part. Mr. Schlagintweit states the fact here made use of as a general one, remarking that in regions other than the Punjab, where the character of the "rainy season" prevails, the decrease of temperature with height is more rapid than in any other part of the year.*

329. We have yet to explain how it is that the winds of the Deccan from November to January have large east duration components and relatively small north duration components. For the quarter September to November, and in a less degree for the quarter December to February, the isothermals in the Messieurs Schlagintweit's charts, after entering the western coast, decline in their passage across the Deccan to the southward: this implies that in proceeding along a parallel of latitude, or still more in proceeding along lines at right angles to the coast, from the coast towards the interior the temperatures (reduced to sea level) would be found to decrease; in other words, the interior, which during the summer was warmer than the western coast, is now colder; and doubtless because now the soil gives off more heat than it receives, as in the summer it absorbed more than it radiated. The surface convection currents due to this variation of temperature will flow from the interior towards the coast, and will exaggerate the easterly components of the north-east trade-wind currents in their flow across the Deccan.

330. A remarkable feature of the temperature distribution and wind prevalences of the month of April is worthy of special notice. In March, already a region of maximum

* "India and High Asia," Vol. IV., page 450.

temperature has begun to form in Guzerat, and away from the coast it has extended in April to Sind on the one hand and Malwa on the other, the increase of temperature between March and April being in this region much greater than in the Konkan and Deccan. Simultaneously the prevailing winds have lost their north components, and without having yet acquired south components. These phenomena we regard as indicating the birth and early growth of what at a later period becomes *the* thermal equator, occupying regions near the southern coast of Western Asia, and having a projection through the Indian Peninsula. We do not, however, suppose that the oceanic thermal equator of the winter season has yet travelled so far north over the Arabian Sea as to coalesce with the newly formed land equator; and thus there will be two medial lines towards which the intervening surface air will tend, one passing through Sind, Guzerat, and down the middle of the Indian Peninsula, and the other, on its course across the Arabian Sea, yet to southward of the Konkan. It is probably the northward passage of this latter line that determines at successive places along the coast the so-called break of the monsoon, which constitutes the commencement of the monsoon rains. As the winds of the Konkan come from over the sea in April, they may be expected to bring with them to the coast some of the motion towards the oceanic thermal equator which they possess in their previous course; and so we find, in the neighbourhood of Bombay, winds with considerable north components, and at Goa, winds with small north components, the smallness in the latter case being a consequence of the greater nearness of Goa to the medial line advancing from the southward. In the Southern Konkan it appears therefore that the influence of the oceanic medial line prevails at this season over that of the medial line through Guzerat and Sind.

331. It is perhaps advisable that we should here roughly indicate the character of the winds that may be expected during the south-west monsoon to blow on the eastern side of the Indian portion of the thermal equator. We observe first that the isothermal lines on the western border of the peninsula lie closer together than those on the eastern border: this means that the rate of increase of temperature inland is greater on the west than on the east side, and therefore the surface winds of the local convection currents formed on the western will be stronger than those on the eastern side, the direction of the normal monsoon winds over the sea on both sides of India being from south-west. The superposition of the local currents upon these will tend on the western side to enhance the monsoon wind, but on the eastern side will determine deviations of the monsoon current near the eastern coast to the left of its course, and this continuing will give a left-handed curvature to the stream lines of the current: thus these lines tend more and more towards the thermal equator. The left-handed curvature we should expect to be somewhat sharp near the junction of the thermal equator with the sea, and to become gradually slower and slower in stream lines further removed from the region of this junction; and on the reapproach of these lines to the thermal equator inland we should expect, moreover, that they would acquire a northward tendency, due to the increase of temperature along the thermal equator northward. Far in the interior it is not improbable, however, that the outflow of the lower strata of air—mentioned in the latter part of paragraph 311—may modify, mask, or even preponderate over the tendencies towards and along the thermal equator that have just been described.

Effect of Change of Level on the Dew Point of a Body of Air.

332. Before attempting to explain the nature of the connection between the physical geography and rainfall of the country, it is desirable that we should lay down, somewhat more clearly than is done in text books on meteorology, a general principle which is the key, if not to the whole problem, at least to the salient points of it. The following proposition embodies the principle in question:—If a large body of mixed air and vapour, such (say) as constitutes the monsoon current of the western coast of India, be lifted by a mechanical force external to itself, and with some degree of rapidity, from one level to a higher level, either by a vertical, oblique, or curvilinear path, the vapour associated with the air will either be partly condensed, or the temperature will be nearer to the dew point than it was at the lower level; and conversely, if a body of air and vapour descend by like means from one level to a lower level, the temperature will be further from the dew point at the low level than it was at the high level; or if some particles of water be suspended in the air as cloud at the upper level, they will be wholly or partly absorbed in the fall to the lower level. Sometimes it is argued as if an equivalent of this proposition was established when it is correctly stated that the upper regions of the atmosphere are cooler than the lower, and that therefore the lifted air becomes cooled, and the lowered air heated; other writers explain that a body of raised air will expand by reason of the diminished pressure which it is subject to at the higher level, and that in expanding it does work and decreases proportionally in temperature; and, as nothing is said to the contrary, the reader is left to infer that if as much work is done as is equivalent to the heat that would have had to be abstracted to reduce the air and vapour at the lower level to the temperature of the dew point, it will have the same effect at the upper level. This, however, is not at all the case; in rising the vapour has expanded along with the air, and more heat must be abstracted from the air and vapour (or equivalent work done) to reduce the latter, in its rarer condition at the higher level, to the dew point than was necessary at the low level. The proposition is not proved then unless this excess quantity of heat is less than the equivalent of the work done by the air in expansion, together with the heat given off by conduction with or without mixture with the cool air of the upper region. As we restrict ourselves to the consideration of a stream of air of large body moving somewhat rapidly, this body, with such temperature as is inherent in it, will determine the temperature of the upper region considered, the conduction of heat to or from the portion of the atmosphere above and at the sides of the current being negligible, as affecting the temperature of the body of the current. Indeed, in the case in which no condensation takes place, the lifted air will generally have a lower temperature than that which is normal to its raised position. We have therefore to show that the heat equivalent to the work done in expanding when air rises from a level of barometric pressure p to a level of pressure p' is greater than the excess of the heat that must be abstracted to reach the dew point at the upper level above that which must be abstracted to reach the dew point at the lower level, the initial temperature at the upper level being supposed, in reckoning the excess, the same as at the lower level.

333. Let us first consider the case in which p' is indefinitely near to p and equal to $p - \Delta p$; and let P be the pressure of vapour in inches of mercury at the lower level; then, providing no condensation take place, the pressure of vapour at the upper level will, by Boyle's

law, be $\frac{p-\Delta p}{p}$ P, the vapour having expanded in the same proportion as the air, and the increase of $\mathrm{P} = -\frac{\mathrm{P}}{p}\Delta p$.

Now Sir William Thomson has shown that in an atmosphere of dry air, agitated as we have supposed by frequent and somewhat rapid changes of level of large bodies of air, the temperature (t) at different heights would follow a law of relation to the barometric pressure expressed by the formula

$$t = c\, p^{\cdot 290} \tag{35}$$

this law being that which is given by the condition that a body of air in moving from one level to another shall neither gain nor lose heat, so that its change of temperature will be determined by the work which is done by or upon it during the change of position.* c is a constant which we shall not require to determine, and t is expressed in Fahrenheit degrees reckoned from the absolute zero of temperature. Although the air is mixed, in the question before us, with a small proportion of vapour, the law may be applied as it stands with a sufficient degree of approximation for our present purpose, so long as no condensation of vapour takes place.

Differentiating (35) we obtain

$$\frac{dt}{dp} = \cdot 290\, c\, p^{(\cdot 290-1)} = \cdot 290\, \frac{t}{p} \tag{36}$$

which is the rate, per inch of mercury, of increase of t with increase of p.

334. Again, Rankine has given the following formula connecting the pressure of vapour with the dew point, and we find it in close agreement with Regnault's experimental values within the ordinary range of atmospheric temperature:—

$$\log_{10} \mathrm{P} = \mathrm{A} - \frac{\mathrm{B}}{\mathrm{T}} - \frac{\mathrm{C}}{\mathrm{T}^2} \tag{37}$$

where P is expressed in pounds of pressure on the square foot, T in Fahrenheit degrees reckoned from the absolute zero of temperature (= 461°·2), and B = 2731·6; C = 396940.

Differentiating (37) we obtain

$$\cdot 4343\, \frac{d\,\mathrm{P}}{\mathrm{P}} = \left(\frac{\mathrm{B}}{\mathrm{T}^2} + \frac{2\,\mathrm{C}}{\mathrm{T}^3}\right) d\,\mathrm{T} = \frac{\mathrm{B}}{\mathrm{T}^2}\left(1 + \frac{2\,\mathrm{C}}{\mathrm{B\,T}}\right) d\,\mathrm{T}$$ (·4343 being the modulus of the common logarithms), (38)

and

$$\frac{d\,\mathrm{T}}{d\,\mathrm{P}} = \frac{\cdot 4343\,\mathrm{T}^2}{\mathrm{B\,P}} \cdot \frac{1}{1 + \frac{2\,\mathrm{C}}{\mathrm{B\,T}}} \tag{39}$$

or, as P enters with the same dimensions on both sides, the same formula (39) will give the rate, per inch of mercury, of change of temperature of the dew point with change of vapour pressure, when the latter is expressed in inches of mercury instead of in pounds weight.

335. According to Dalton the relation of the dew point to the pressure of vapour is the same whether or not the vapour is mixed with air;† hence Rankine's formula, and with it

* We have also given a demonstration of this law in paragraph 283.

† Dr. Andrews has recently pointed out that this is not strictly accurate; and our results will require modification when the requisite data become available.

equation (39), is applicable as well to vapour mixed with air as to pure vapour; but in the former case the quantity of heat required to produce the change of temperature will be that which is required to heat (or cool) the vapour, *plus* that which is required to heat (or cool) the air associated with it, and in comparison with this latter quantity the former will be very small.

336. In applying equations (36) and (39) let us confine our attention to a definite quantity of air. Equation (36) shows the ratio of its fall of temperature to the decrease Δp of the pressure; and with the corresponding decrease of vapour pressure $\frac{P}{p}\Delta p$ substituted for Δ P, equation (39) shows the ratio of the depression of the dew point of the same quantity of air to the change of vapour pressure, or

$$\frac{d\,T}{d\,P}=\frac{\Delta\,T}{\frac{P}{p}\Delta p}=\frac{\cdot 4343\,T^2}{B\,P}\cdot\frac{1}{1+\frac{2\,C}{B\,T}} \tag{40}$$

and multiplying both sides by $\frac{P}{p}$

$$\frac{\Delta\,T}{\Delta\,p}=\frac{\cdot 4343\,T^3}{B\,p}\cdot\frac{1}{1+\frac{2\,C}{B\,T}} \tag{41}$$

which gives the ratio between the depression of the dew point and the fall (Δp) of barometric pressure. But for a given value of Δp the quantity of heat that must be abstracted from the body of air considered to reduce its temperature by Δ T is the same as the difference between the heat that would have to be abstracted to reach the dew point at the upper and lower levels respectively. We have therefore to show that it is less than the heat that must be abstracted from the same body of air to reduce its temperature by Δt, the equivalent of the work done in expanding till the barometric pressure is diminished by Δp; or, as Δp is the same in both equations, it comes to the same thing as showing that the difference of temperature Δ T in equation (41) is less than Δt in

$$\frac{\Delta\,t}{\Delta\,p}=\cdot 290\,\frac{t}{p} \tag{42}$$

or dividing (42) by (41), that

$$\frac{\Delta\,t}{\Delta\,T}=\frac{\cdot 290}{\cdot 4343}\,\frac{t}{T^2}\,B\left(1+\frac{2\,C}{B\,T}\right) \tag{43}$$

is greater than unity; or inserting numerical values, that

$$\frac{\Delta\,t}{\Delta\,T}=\frac{\cdot 290}{\cdot 4343}\times 2731\cdot 6\left(1+\frac{290\cdot 6}{T}\right)\frac{t}{T^2}=1824\cdot 1\left(1+\frac{290\cdot 6}{T}\right)\frac{t}{T^2} \tag{44}$$

is greater than unity.

As T is equal to or less than t, $\frac{T^2}{t}$ is equal to or less than t, and can under no practical conditions approach even at all nearly to 1824·1, and therefore the expression (44) is greater than unity; and the proposition is proved for infinitesimal movements at any level up to and beyond the greatest attainable heights; hence, as it is true for all infinitesimal liftings from the sea level up to such height, it is true for any integral change of level included between the same limits.

337. If the air rise till the pressure is just so great that the vapour associated with it is at the temperature of its dew point, this temperature will also be that of the air, or

$$t - \Delta t = T - \Delta T, \text{ and } t - T = \Delta t - \Delta T \tag{45}$$

whence, and from equation (44), we have approximately

$$t - T = \Delta T \times 1824{\cdot}1\left(1 + \frac{290{\cdot}6}{T}\right)\frac{t}{T^2} - \Delta T, \text{ or}$$

$$\Delta T = (t - T) \div \left\{1824{\cdot}1\left(1 + \frac{290{\cdot}6}{T}\right)\frac{t}{T^2} - 1\right\} \tag{46}$$

and the temperature of the air and of the dew point at the upper level is nearly

$$T - \Delta T = T - (t - T) \div \left\{1824{\cdot}1\left(1 + \frac{290{\cdot}6}{T}\right)\frac{t}{T^2} - 1\right\} \tag{47}$$

Also, putting the values of Δt and ΔT given by (41) and (42) in (45), we obtain

$$t - T = \Delta p\left\{-\frac{{\cdot}4343}{B}\frac{T^2}{p}\frac{1}{1 + \frac{2C}{BT}} + \frac{{\cdot}290\,t}{p}\right\} \tag{48}$$

and approximately (inserting numerical values)

$$\Delta p = \frac{p\,(t - T)}{{\cdot}290\,t - \frac{T^2}{6289{\cdot}7}\frac{1}{1 + \frac{290{\cdot}6}{T}}} \tag{49}$$

and the pressure at which condensation begins is approximately

$$p - \Delta p = p\left\{1 - \frac{t - T}{{\cdot}290\,t - \frac{T^2}{6289{\cdot}7}\frac{1}{1 + \frac{290{\cdot}6}{T}}}\right\} \tag{50}$$

338. Above this point, vapour will be condensed, t and T will be identical until the air ceases to rise, and the relation $\Delta P = \frac{P}{p}\Delta p$ will no longer hold good, but instead of it P will vary solely with t; for equation (44) is still applicable to show that the loss of temperature due to work done under the decrease of pressure exceeds the depression of the dew point that would result from the diminished pressure if no work was done or heat lost: hence the diminution of temperature beyond what is necessary to keep the vapour at its dew point will cause some of the vapour to be condensed. The decrease of temperature will no longer be determined by the work done in expansion alone, but by the excess of the heat equivalent of that work above the latent heat liberated in the condensation of part of the vapour.

339. Equations (46) and (49) give approximate values only of ΔT and Δp, because equation (35) only approximately represents the relation between the pressure and temperature of dry air mixed with a small proportion of vapour, and because the variation of t and T between the pressures p and $p - \Delta p$ is not allowed for. It would be easy to obtain more exact values by constructing a table showing values of t with argument p from equation (35) with an assumed convenient value of c, and using it conjointly with Regnault's table of vapour pressures corresponding to different temperatures. But in the actual cases that we use for illustration—other than estimations of the pressure at which condensation commences—we shall avoid both these errors by dealing directly with the integral changes of vapour pressure and amounts of work done.

Calculated Heights at which Condensation commences.

340. Applying equation (49) with the monthly mean values of p, t, and T at Bombay as data,* to find the diminution of pressure that must take place before condensation of vapour begins, we obtain the following results :—

TABLE 156.

	Δp	Corresponding approximate Height.
Jauuary - - -	2·365	2,355
February - -	2·477	2,484
March - - -	2·114	2,130
April - - -	1·961	1,991
May - - -	2·089	2,134
June - - -	1·440	1,453
July - - -	·981	976
August - - -	·963	954
September - -	1·079	1,069
October - - -	1·454	1,450
November - -	2·417	2,433
December - -	2·403	2,403
Year - - -	1·735	1,738

Distribution and Variation of Rainfall.—Comparison of Fact with Theory.

341. The numbers in the last column show the approximate heights to which air in the normal state at Bombay in the several months of the year must be lifted without mixture with other air, before cloud or rain begins to form in it. This height in July and August is less than a thousand feet, whilst in the winter months December to February it is about 2,400 feet; and all through the monsoon from June to October it is much less than the height of the ridge of the Western Ghauts near the latitude of Bombay. Consequently, making the obvious assumption that the air of Bombay is during the monsoon typical of that of the coast of the Konkan generally, the region which approaches the Ghauts from the western side will be generally rainy in all those months, June to September, when the winds above and below the Ghauts show that, on the average, a continuous stream of air flows from the sea over the ridge of the Ghauts and onward towards the east. On the other

* For which see Table 157, paragraph 358, further on.

hand, from November to May the height at which condensation would begin is greater than that of the Ghauts, and hence, although the westerly coast winds of May and part of April undoubtedly continue and carry the air to some extent over the Ghauts, these months are generally rainless or nearly so; and once beyond the ridge of the Ghauts, the tendency of the moving stream will be rather downward than upward, following the decline of the ground surface, so long at least as winds with a westerly component continue to be the prevailing ones over the Deccan plateau; for otherwise there would be no source from which to supply the place evacuated by the eastward outflow of surface air. The descent, as we have explained in paragraphs 332–6 puts the air into a state of less readiness to part with its moisture; and the surface temperature, which at this season is shown by the isothermals to increase as we proceed inland, and which the stream takes up as it passes, still further adds to the retaining power of the air for the vapour which it carries. But notwithstanding both these influences, the air flowing over the Deccan in April and May, when it comes from the Konkan, has a temperature much nearer to its dew point than the same air in its previous passage over the Konkan; and consequently the liability to the occurrence of rain at this period is greater on the Deccan than in the Konkan, for it must be remarked that the heights in Table 156 refer to the average condition of the air at Bombay during the respective months, and that as in the course of a month the conditions both as to barometric pressure, vapour pressure, and temperature vary, so the heights will sometimes be greater and sometimes smaller than the averages, and the average heights for April and May are so little above the general height of the ground surface of the Deccan, that it may well happen that abnormal depressions of temperature or barometric pressure, or both, on the plateau determine the commencement of condensation and the formation of cloud, and even occasional falls of rain.

342. Regarding the south-west monsoon in the manner that we have described in paragraph 321 as the lower part—tending towards the thermal equator—of a circulating system of winds, the surface stream must have at each point of its course a limited depth. Directing the attention to the vertical section of the stream at right angles to its course and over the ridge of the Ghauts, and looking back from this section towards the Arabian Sea, upon the stream lines* of the advancing air, it is in accordance with the views of the most advanced writers on fluid motions to expect that, before actually reaching the obstacle which the line of the Ghauts constitutes, the stream lines will begin to deviate upward from their horizontal course, and will continue to do so till they reach the ridge. The theoretical distance at which the deviation will commence is infinity, but the deviation remains practically inappreciable till the obstacle is somewhat nearly approached. On the coast of the Konkan, the average gradient between which and the ridge of the Ghauts is, perhaps, one in a hundred, the deviation may be supposed to have become considerable, and the rate of change of the deviation, which is what determines the continued condensation of vapour, sensible. Approaching the Ghauts the inclination of the stream lines to the horizon increases and becomes a maximum at a point where—or somewhat beyond, and before reaching the ridge —the rainfall should be heaviest. Beyond this point the inclination decreases, and at or near the ridge vanishes. Eastward of the ridge the stream lines incline downward so long as

* A stream line may be defined as the path of an individual particle of the flowing stream.

westerly winds prevail on the ground surface. In this way we attribute the increasing rainfall, as the Ghauts are approached from the coast, to the increasing rate of uplifting of the air corresponding to the increasing inclination of the stream lines. Eastward of the ridge the further formation of rain by the process of lifting ceases, but at this point the air is not only to a large extent saturated with vapour, and therefore in the most favourable condition for yielding up to the ordinary influences which produce rain over a level country a portion of that vapour, but it is already highly charged with falling raindrops, which will take time to reach the ground. During this time the stream will have advanced a certain distance to eastward of the ridge, and a greater or less distance according to the velocity of the wind. Consistently with these notions we find that the rainfall diminishes as the ridge of the Ghauts is receded from to eastward, and that a longitudinal band of minimum* rainfall gradually approaches the Ghauts as the velocity of the monsoon wind dies away between August and October. We would remark that as the decline of the ground surface of the Deccan to eastward of the Ghauts is generally at a slow rate, the counteracting influence to the formation of rain which the general descent of the air constitutes will not be of large magnitude until the eastern border of the central plateau of the Indian Peninsula is reached; and, long before that border is reached, the westerly surface winds, without which we cannot conclude that there is a descent, have dwindled to an extent which leaves them scarcely entitled any longer to be called preponderating winds, or they have given place to prevailing winds which have an easterly component. But there is another reason why rain should fall to the eastward of the ridge of the Ghauts, which is also connected with the modification of character of the winds just mentioned. The thermal equator at this season (the monsoon) cuts the central and southern parts of the Indian Peninsula in a north and south direction nearly in the middle, and winds blow towards it, as the medial line, from both sides of the peninsula. The stream lines of these winds ascend on approaching the medial line, and curve backward towards the direction of their former course, the curvature of the ascending portions of the stream lines being less and less the nearer the lines approach the medial line; thus the upward motion of the air, and consequently the formation of rain, will be greater and greater as the medial line is approached. It is to this cause that we attribute the increase of rainfall that is observed, in the months July to October, to eastward of the minimum band; and the neighbourhood of the medial line, being presumably one of maximum rainfall, it is to be expected that as the part of the thermal equator occupying the range of latitude of the Konkan moves westward and twists, as it does, in a left-handed direction, it will carry towards the region which it approaches an increased rainfall, and leave those behind it with a diminished rainfall. That it does the former we have evidence in the facts that, whilst the monsoon rainfall on the Ghaut border is in September and October very much diminished, it is kept up (or nearly) to the standard of August on the eastern side of the Deccan, the latter fact being, we infer, a consequence of the nearer approach (from eastward) of the medial line; and this idea is further borne out by the considerable increase between September and October of the rainfall in the southern part of the Deccan, which is crossed by the thermal equator in October; and also by the fact that both in the Konkan

* Why minimum will be presently explained, the rainfall decreasing from the Ghauts on the one hand, and from the thermal equator on the other hand.

and Deccan there is in October a decrease of rainfall as we proceed northward from the region crossed by the medial line; and yet again, by the facts that the light occasional rains which follow the monsoon continue till later in the year in the southern than in the northern parts of both the Deccan and Konkan, and are also of greater amount. That in October the thermal equator crosses the southern part of the Deccan we have not only the evidence afforded by the Messieurs Schlagintweit's isothermals, of which a maximum line of 80° passes about 30 miles south of, and parallel with, the Deccan portion of the course of the Godávari river, and encloses—with another line of 80°—all of the Bombay side of the Deccan southward but a very narrow strip of the edge of the Ghauts, but the wind arrows of our map for October are (with the exception of that of Manderdeo, which is for a period of a single month only) all short for this region, indicating that the change from the summer to the winter character of winds is in progress; and besides, whilst winds with a north component have already obtained a footing in the northern half of the Deccan portion of this region, the winds of the stations Sholápur, Kolhápur, and Belgaum have yet a scarcely perceptible north component, or still retain a small south component.

343. Taking now the ascent of the Western Ghauts during the monsoon months as a typical instance of the fulfilment of the conditions necessary for the formation of rain in moist surface currents rising with the contour of the country, we may find a typical complementary instance, in which the requisite conditions are not fulfilled, in the flow of monsoon air up the Thar or Indian Desert. That winds from the south-west quadrant are the prevailing winds in this district during the monsoon there can be little doubt; for on the one hand we have such winds blowing with great persistency on the northern borders of the Malwa plateau—at Ajmir and Násirabad—and with some preponderancy on the other hand at Mooltan on the Indus; also the prevailing winds of Northern Guzerat and Lower Sind—notwithstanding the diversion in Upper Sind towards the junction of the Hala and Suleiman mountains—blow almost directly up the Thar. Mr. Trelawny Saunders tells us that between the basins of the Ganges and Indus rivers the lowland rises to an elevation of only 900 feet; consequently the average gradient from this region to the coast of Lower Sind is only about $1\frac{1}{2}$ feet per mile, and for the half nearest the sea it is probably not more than one foot per mile. Assuming then what is highly probable, that the air of the monsoon current which reaches the coast of Sind is not more moist than that which flows over Bombay, we see that the minimum height at which vapour would begin to be condensed, viz., 954 feet in the month of August, is not reached even at the head of the Thar. But there is another powerful reason why the moisture of the monsoon current should not be deposited as rain in this region. Beyond Bombay the current grows cooler and cooler till it reaches the ridge of the Ghauts, a consequence chiefly of the work which it is doing in expanding; but in the Thar, notwithstanding the small amount of work which the air does in rising at the rate of a foot and a half per mile of progress, the surface temperature increases. According to the isothermals of the Messieurs Schlagintweit the increase from the coast of Lower Sind up to longitude 75°, near the upper limit of the Thar, is in the months June to August about 8°; and this is in agreement with the high temperatures shown by our own maps along the whole northern boundary of our sphere of observation, viz., from Upper Sind to Malwa. Hence, seeing that the dew point decreases by reason of expansion of the air in rising, the air in its progress along

the Thar will have temperatures departing further and further from the respective dew points, and the retaining power of the air for its own moisture will thus be increasing. It is not impossible too that the air may be robbed, on its way, of some of its moisture by the deposition of dew, thus reducing the dew point by another means besides expansion of the containing air; but notwithstanding this and the reputed aridity of the soil, we venture to predict that observation will hereafter show that the air of the Thar, at least in the half nearest the sea, is not, during the south-west monsoon, in any sense a dry air.

344. It may add something to the force of the foregoing remarks if we state the extent to which the air is dried by condensation of its vapour in a district which, under the most favourable conditions, experiences the most copious rainfall; such a district is that which intervenes between Mahableshwar and the coast to windward of it in July and August; and here the surface air on the coast loses scarcely more than one fourth of the vapour contained in it in the ascent to the top of the Ghauts. (See paragraph 358.)

345. If the reader will now read over again the notes on the rainfall of the Presidency (paragraphs 262 to 274), with the rainfall maps before him, he will find that much that there appears, at first casual and disconnected, becomes, under the guiding idea that we have been endeavouring to elucidate, connected and systematic. He will find, for instance, a small rainfall along a line extending from Tatta, in Sind, to Tando Alâhyar, a district in some degree under like conditions to the Thar; whilst to the north and north-east of this district, where the diversion of the winds towards the high lands of the Hala and Suleiman mountains is felt, the upward course of the stream lines determines a considerably greater fall; and that the increase of fall does not continue to Upper Sind is sufficiently accounted for by the great increase of temperature in that direction. Beyond, in the north-east direction, we come to Umarkot and Khipra with larger falls, consistently with their being in a district *from* which such occasional drainage as exists appears to flow; and of the two stations, that which appears, from the drainage marked on our map, to be the higher (Umarkot) has the greater rainfall.

346. Again, he will observe that the line of the Western Ghauts, which, south of Bombay on the whole recedes from the coast, though only slightly, as far as Goa, recedes in a marked manner to the northward of Bombay, and with a slight increase of rate towards the northern limit of the line; also that south of Goa, from Karwar to Honáwar, the Ghauts, though relatively low, approach very near to the coast. It follows from these facts that on the coast the upward direction of the stream lines of the monsoon current will be most developed in the Karwar-Honáwar district, next between Goa and Bombay, and least north of Bombay; in this order, therefore, the rainfall on the coast should decrease; the observed facts are in strong accord with this requirement. A similar explanation we have already given of the increase of rainfall from the coast to the ridge of the Ghauts; to this we need only add now, that the rapid increase near the ridge is consistent with a rapid development of upward direction of the stream lines, due partly to local convection currents

caused by lateral increase of temperature eastward,* and partly to the large gradient between the foot and the ridge of the Ghauts; for although the almost abrupt change of gradient of the ground surface will have no abrupt counterpart in the stream lines, it will yet in some degree impress its own character upon the course of these lines.

347. Of notable instances of an increasing rainfall with a moist current passing over rising ground, and of decreasing rainfall in passing over declining ground, he will find, besides those already referred to, the following: (1), an increase on the Sind Railway on reaching the Sattara hills, the fall of Meting being about twice as great as the average on the level part of the railway towards Kurrachee; (2), increase generally up the rivers of Guzerat, and particularly on the left slope of the basin of the Mahi river, reaching 42 inches and declining beyond to 28 inches on the eastern or declining slope of a range of hills branching northward from the Vindya mountains, and having the Anass river in the valley to eastward of it; (3), Rajkot, which is somewhat elevated—rivers rising in its neighbourhood and flowing in all directions—has a larger fall than stations near the eastern side of Kattywar; (4), Niphád and Vinchur, being near the source of the Godávari river, are about 100 feet lower than Nandur and Lasalgaon on the Great Indian Peninsula Railway; thus there is a considerable decline of the ground towards the river; and the rainfall of the two low stations is systematically lower than that of Násik and Sawargaon, which are at a greater distance from the river, the one on the one side and the other on the other; (5), the current must generally decline somewhat in crossing a river-course, and an instance of its doing so sufficiently to reduce the rainfall of the slopes near the river-course, as compared with the higher and more distant parts, is found in the upper course of the Bhima river, in a district extending from Sirur to Palanpur; and less marked instances occur, one near the course of the Krishna river towards our eastern boundary, and the other in the upper part of the valley of the Godávari; and (6), a sensible increase of rainfall in the upper part of the Tapti valley on ascending from the course of the river towards the sources of its higher tributaries in the left basin; leading to a surmisal, which is in some degree supported by the monsoon winds of Málegaon, that a part of the monsoon current reaches the district by way of the Tapti valley, and only a part from above the Ghauts.

348. And, again, of variations with the progress of the thermal equator, the approach and recession of the medial line producing respectively increase and decrease of the rainfall, and thus giving a larger fall, other things being the same, to stations near to it than to others more remote, he will find instances—additional to those already mentioned—first, in the greater rainfall of the month of May in the south than in the north of the Deccan; secondly, in the decrease on the eastern side of the Deccan and in the minimum band from June to July, the thermal equator having since June passed further to eastward; and, thirdly, in the increased fall in the northern part of the minimum band of the Deccan between July and August, the medial line having again come nearer. Also, he will find that in the month of May there is less rain in the Konkan about Bombay than either further north or further south, a fact which consists with the supposition that at this time

* See paragraph 384 further on.

Bombay lies in the space intervening between the newly formed land thermal equator and the pre-existing thermal equator over the Arabian Sea; for on this supposition the upward course of the stream lines, and consequently the deposition of rain, will, so far as this cause is concerned, be less marked near Bombay than on a closer approach to either of the two medial lines.

349. It will not be out of place if we draw attention here to the analogy that exists between the conformation of the land which borders the eastern side of the Bay of Bengal, and that which borders the Arabian Sea from the mouth of the Tapti river southward; in both cases a line of mountains rises abruptly from the sea coast, or from a short distance inland, and runs the whole length of the coast, presenting a full front towards the direction west-south-west; in both, the moist surface currents of the south-west monsoon are met by the steep faces of the mountains, along which they rise, depositing a part of their vapour, as rain, on the way; consequently the strip of country intervening between the ridge of the line of mountains, or a little further inland, and the sea coast, is in both cases, during the prevalence of the south-west monsoon winds, excessively rainy, and in both cases for the same reason.

Diminution of Rainfall with Increase of Elevation of the Gauge.

350. In paragraphs 341 and 342 we have attributed the heavy rains of the coast of the Konkan to the upward deviation which characterises the course of the stream lines of the monsoon current, as well in passing the coast line as in the remainder of its progress towards the Ghauts. Successive stream lines may be regarded as enclosing curvilinear layers of the atmosphere, each of which will contribute its quota to the rainfall of a place over which it passes. The raindrops formed in any one of these layers will contribute nothing to the rain received in a gauge placed at a higher level than that layer, though the gauge will receive the rain formed in all the layers above itself. Here then we have a partial explanation of the fact observed at Bombay, and stated in Table 67, paragraph 124, of Part I.,—that, whilst 67·01 inches of rain is received in the course of the year in a gauge placed $4\frac{1}{2}$ feet above the ground, only 59·74 inches is received in a gauge placed 46 feet above the ground. We will first show that an assumption that herein may be found a complete explanation of this fact is untenable. Making the assumption, and also assuming, as a rough approximation, that layers containing, in a square foot of horizontal section, equal quantities of air, deposit equal quantities of rain, we may from the figures given form a rough estimate of the height of that lower portion of the monsoon current at Bombay from which is extracted the rain that falls. In ascending in the atmosphere equal changes of barometric pressure correspond (nearly enough) to the passage through layers containing equal quantities of air. The change of pressure at Bombay between the heights $4\frac{1}{2}$ and 46 feet is during the monsoon ·043 inch. The same stratum of air yields 7·27 inches of rain; therefore the change of pressure that will yield 67·01 inches of rain is $\frac{67\cdot01}{7\cdot27} \times \cdot043 = \cdot396$ inch; and this corresponds to a height of 543 feet. Hence, adding the height of the lower gauge, the total approximate average height above the ground of the rain-forming aggregate stratum of air is 547 feet.

351. We may, by attributing the condition in which the air during the monsoon is found at Poona to a station—which will be nearly of the same height as Poona—on the

ridge of the Ghauts and to leeward of Bombay, and by estimating the average rainfall between Bombay and the Ghauts, form another estimate, from independent data, of the average height of the rain-forming part of the monsoon current between Bombay and the Ghauts. We take for the horizontal distance of the ridge of the Ghauts to leeward of Bombay 50 miles, and for an average general velocity of the wind the velocity at Bombay. We find from Table 157 that a grain of air in rising from the height of Bombay to that of Poona loses on the average from June to September ·0038 grains of vapour. This aggregate loss we are to attribute to a horizontal progress of 50 miles; the rate of loss per foot of horizontal progress will therefore be $\frac{\cdot0038}{50 \times 5280} = \cdot000,000,01439$ grain; that is to say, every grain of air that passes over the place of average rainfall deposits ·000,000,01439 grain of rain. The mean velocity of the wind is 13·3 miles per hour; therefore the movement in the 122 days from June to September is $13\cdot3 \times 5280 \times 24 \times 122 = 205,615,872$ feet. If we regard the grain of air over the place of average rainfall as having a horizontal section of one square foot, the number of grains that will successively occupy the space in the four months will be 205,615,872; and therefore the rain deposited per square foot by a stream of the height of a grain of air which has one square foot of horizontal section is

$$205615872 \times \cdot000,000,014,39 = 2\cdot959 \text{ grains.} \qquad (57)$$

Now taking 95 inches as the average rainfall, and using 436,000 grains as the weight of a cubic foot of water, the number of grains of water deposited on a square foot of surface is $\frac{95}{12} \times 436000 = 3,451,667$; and dividing this by the right side of (57), we obtain, for the number of grains of air contained in the column that will deposit in the four months 95 inches of rain,

$$\frac{3451667}{2\cdot959} = 1166498. \qquad (58)$$

Dividing this again by 495,088—the number of grains contained in a column of mercury one inch high and of one square foot of horizontal section—we find the weight of the column, expressed in inches of mercury, to be 2·356. The height corresponding to this is 2,399 feet, and it must be supposed to be measured above the average height at which condensation commences.

352. The extravagant difference between the two results—547 feet and 2,399 feet—is doubtless due to the wrong assumption, in the first case, that as much rain is formed for every ascent corresponding to a depression of ·043 in the barometric pressure as is found in the first ascent from the lower to the higher gauge. The breaking of the raindrops into spray on striking the ground,* and the retention of the spray for some time by the lower layers of the atmosphere, furnishes a reason why the difference of rainfall at the top and bottom of a surface layer should be no measure of the rain formed in the elevated layers of corresponding mass; for the same water does duty as rain again and again in the surface layer, but only once in the elevated layer. The reason why this is so is that, once formed, the spray is lifted along

* In the course of his reading, the writer has somewhere seen this action advanced in explanation of the excess rainfall received in low rain gauges, apart, however, from the *definite* system of upward currents which is here combined with it, and is essential to the completeness of the explanation.

the stream lines of the monsoon current to a greater elevation till the particles—reinforced by fresh condensation once more falling, coalesce and reform into raindrops; and it is obvious that of these manifold-duty-doing raindrops, a gauge receives all that are reformed above it and none of those reformed below it; and nearly all that it receives it retains, since the protected space in which the spray is formed within it forms no part of the course of the ascending air current. Hence there should be a gradation of decreasing rainfall, sensible up to a moderate limit, with increasing height of the gauge; and this in far larger degree than is due to simple condensation in the layers of air intervening between the respective gauges.

353. In our remarks on the nature of cyclones (paragraph 382) we explain that the commencement of rain implies generally the simultaneous establishment of convection currents with upward movement in the neighbourhood of the falling rain; but if such currents exist generally when rain is falling, the general fact of the decrease of rainfall with increase of height above the ground may be explained in the same manner as in the particular case of Bombay.

Hygrometric Quality of the Air.

354. It was suggested many years ago by Dr. Balfour Stewart that the most serviceable expression for the hygrometric condition of the air would be the ratio of the quantity of vapour contained in a given volume to the quantity of dry air contained in the same volume, which ratio he called the "hygrometric quality" of the air. Adopting the suggestion, we find an equivalent quantity—the mass of vapour associated with a grain of dry air—in the following manner :—

Let

M = the mass of vapour associated with a grain of dry air.
p = the barometric pressure (expressed as in paragraph 278).
t = the temperature (ditto).
P = the pressure of vapour (ditto).
T = the temperature of the dew point (ditto).
v = the volume, in cubic feet, of a grain of dry air *plus* its associated vapour, when the barometric pressure, temperature, and temperature of the dew point are p, t, and T respectively.
ρ = the density of the same (to same standard as in paragraph 278).
V = the volume, in cubic feet, of a grain of dry air, when $p = 1$ and $t = 1$, $= \cdot 0001078$.

355. Regnault has found that at low pressures and ordinary temperatures the mass of vapour in a given volume of air mixed with vapour is proportional to the vapour pressure; and the ratio of this mass to the mass of an equal volume of dry air at pressure 29·914 and temperature 491°·1 is equal to $0{\cdot}6235 \frac{P}{29{\cdot}914}$; or as the mass of a cubic foot of dry air, at the pressure and temperature mentioned, is 565·0862 grains, the mass of the vapour in a cubic foot of mixed air and vapour is

$$565{\cdot}0862 \times 0{\cdot}6235 \frac{P}{29{\cdot}914} \text{ grains.} \qquad (59)$$

356. Regnault has also found that the relations of the volume, pressure, and temperature of vapour at temperatures above its dew point are approximately the same as for a perfect gas; and it is the practice of meteorologists to apply the law rigidly in calculations concerning the vapour of the atmosphere. Following this practice we find that P being the pressure of vapour at the temperature (T) of the dew point, the pressure at the higher temperature t will be $\mathrm{P}\frac{t}{\mathrm{T}}$: hence, as by the molecular theory of gases the pressure p is equal to the sum of the pressures of dry air and vapour, the pressure of dry air is $\left(p-\mathrm{P}\frac{t}{\mathrm{T}}\right)$; that is to say, if the dry air alone occupied the whole space of the air and vapour, it would exert the pressure $\left(p-\mathrm{P}\frac{t}{\mathrm{T}}\right)$; but it is actually subject to the pressure p, and therefore it occupies only $\frac{p-\mathrm{P}\frac{t}{\mathrm{T}}}{p}$ of the whole volume, being thrust out of the space occupied by the vapour: the vapour must also be compressed (say) in single molecules, whilst the centres of the molecules remain undisturbed and equally distributed through the whole volume, or, according to the dynamical theory, the free path of the molecules of vapour is less than if no air were present, and the molecules, retaining their velocity, therefore come into collision with the corresponding molecules of air, often enough in a given time to require a pressure p to balance their impulses. The mass of dry air in a cubic foot of mixed air and vapour, we now see will be

$$565{\cdot}0862\,\frac{p-\mathrm{P}\frac{t}{\mathrm{T}}}{29{\cdot}914}\cdot\frac{491{\cdot}1}{t}\ \text{grains.} \tag{60}$$

Hence, dividing (59) by (60), we find that associated with every grain of dry air in the atmosphere there is a mass of vapour equal to

$$\mathrm{M}=\frac{0{\cdot}6235}{491{\cdot}1}\,\frac{\mathrm{P}\,t}{p-\mathrm{P}\frac{t}{\mathrm{T}}}=\cdot0012697^{*}\,\frac{\mathrm{P}\,t\,\mathrm{T}}{p\,\mathrm{T}-\mathrm{P}\,t} \tag{61}$$

357. It is convenient to introduce here an expression, which will be of use for future reference, for the mean density of the mixed air and vapour. As the mass of a cubic foot of our substance of standard density is one grain, this is simply the sum of the masses (59) and (60) divided by one grain, or

$$\begin{aligned}\rho&=565{\cdot}0862\left[\frac{p-\mathrm{P}\frac{t}{\mathrm{T}}}{29{\cdot}914}\cdot\frac{491{\cdot}1}{t}+0{\cdot}6235\,\frac{\mathrm{P}}{29{\cdot}914}\right]\\&=565{\cdot}0862\left[\frac{p}{29{\cdot}914}\left\{\frac{491{\cdot}1}{t}-\frac{491{\cdot}1}{\mathrm{T}}\frac{\mathrm{P}}{p}+{\cdot}6235\,\frac{\mathrm{P}}{p}\right\}\right]\\&=565{\cdot}0862\left[\frac{p}{29{\cdot}914}\left\{\frac{491{\cdot}1}{t}-\frac{\mathrm{P}}{p}\left(\frac{491{\cdot}1}{\mathrm{T}}-{\cdot}6235\right)\right\}\right]\end{aligned} \tag{62}$$

358. Applying, now, equation (61) to determine, from mean monthly values of p, t, P and T, the hygrometric quality of the air at seven variously situated stations we obtain the following results.

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* An insignificant arithmetical error of ·000,000,1 in this number has not been corrected, because the number has been used as it stands in calculations that follow.

TABLE 157.

DETERMINATIONS of the HYGROMETRIC QUALITY of the AIR, or the Mass of Vapour (M) associated with a grain of Dry Air, in each month of the year at the Stations Kurrachee, Deesa, Bombay, Poona, Mahableshwar, Goa, and Belgaum.

		January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Year.
KURRACHEE.	p =	30·152	30·091	30·030	29·897	29·780	29·642	29·609	29·691	29·824	29·977	30·102	30·164	29·915
	t =	522·2	525·6	532·6	538·4	541·6	544·6	543·3	540·0	539·7	536·1	530·4	529·9	534·9
	P =	0·406	0·459	0·588	0·719	0·855	0·925	0·906	0·860	0·819	0·696	0·499	0·417	0·679
	T =	512·3	515·7	522·7	528·5	533·7	536·0	535·4	533·8	532·4	527·6	518·0	513·1	526·9
DEESA.	p =	29·703	29·646	29·585	29·478	29·411	29·268	29·241	29·312	29·432	29·552	29·678	29·717	29·502
	t =	524·6	530·0	537·2	547·7	551·6	550·1	544·7	540·7	540·6	538·7	532·7	527·7	538·9
	P =	0·383	0·410	0·459	0·561	0·703	0·813	0·863	0·858	0·809	0·635	0·468	0·403	0·614
	T =	510·7	512·6	515·7	521·4	527·9	532·2	534·0	533·8	532·0	524·9	516·2	512·1	523·9
BOMBAY.	p =	29·938	29·907	29·860	29·798	29·753	29·651	29·649	29·712	29·770	29·829	29·902	29·934	29·809
	t =	532·7	533·5	537·0	540·5	543·3	542·4	539·5	538·7	538·8	539·6	537·7	535·5	538·3
	P =	0·587	0·595	0·707	0·811	0·874	0·931	0·904	0·882	0·869	0·847	0·692	0·644	0·779
	T =	522·7	523·0	528·0	532·1	534·3	536·2	535·3	534·6	534·2	533·4	527·4	525·3	530·9
POONA.	p =	27·977	27·944	27·903	27·847	27·796	27·714	27·717	27·763	27·816	27·888	27·961	27·987	27·859
	t =	530·5	534·1	539·3	543·7	542·8	538·0	534·6	533·5	534·1	535·7	533·7	530·8	535·9
	P =	0·452	0·450	0·503	0·568	0·650	0·715	0·703	0·693	0·682	0·633	0·508	0·471	0·586
	T =	515·3	515·2	518·3	521·7	525·6	528·4	527·9	527·5	527·0	524·8	518·6	516·4	522·6
MAHABLESH-WAR.	p =	25·726	25·713	25·682	25·637	25·600	25·494	25·457	25·508	25·560	25·656	25·678	25·724	25·620
	t =	523·4	527·3	531·5	534·7	532·2	525·4	523·3	523·0	523·0	525·4	524·2	523·3	526·4
	P =	0·386	0·413	0·453	0·502	0·575	0·610	0·593	0·576	0·568	0·516	0·404	0·378	0·498
	T =	510·9	512·8	515·3	518·2	522·1	523·8	522·9	522·1	521·7	519·0	512·2	510·4	518·0
GOA.	p =	29·688	29·658	29·631	29·577	29·547	29·491	29·503	29·535	29·562	29·585	29·648	29·680	29·592
	t =	540·2	540·7	541·9	544·0	544·7	541·2	539·2	538·7	539·4	541·3	541·7	541·1	541·2
	P =	0·694	0·723	0·787	0·850	0·879	0·894	0·878	0·866	0·863	0·867	0·760	0·700	0·813
	T =	527·5	528·7	531·2	533·5	534·5	535·0	534·5	534·0	533·9	534·1	530·2	527·7	532·2
BELGAUM.	p =	27·409	27·385	27·350	27·303	27·271	27·224	27·225	27·258	27·295	27·332	27·382	27·409	27·320
	t =	529·8	533·2	536·6	539·1	537·5	533·1	530·4	529·4	530·5	532·5	531·2	529·5	532·7
	P =	0·472	0·476	0·524	0·595	0·675	0·696	0·681	0·664	0·656	0·624	0·519	0·472	0·588
	T =	516·5	516·7	519·4	523·0	526·7	527·6	526·9	526·2	525·9	524·4	519·2	516·5	522·7
KURRACHEE	M=	·0091	·0103	·0135	·0169	·0203	·0223	·0218	·0205	·0194	·0162	·0114	·0094	·0158
DEESA		·0087	·0094	·0108	·0135	·0172	·0200	·0210	·0207	·0194	·0150	·0108	·0092	·0146
BOMBAY		·0135	·0138	·0165	·0192	·0209	·0223	·0215	·0209	·0206	·0200	·0162	·0150	·0183
POONA		·0111	·0111	·0126	·0144	·0165	·0181	·0177	·0173	·0170	·0158	·0125	·0115	·0146
MAHABLESHWAR		·0101	·0109	·0121	·0136	·0155	·0164	·0158	·0153	·0151	·0137	·0106	·0099	·0133
GOA		·0164	·0172	·0188	·0204	·0212	·0215	·0210	·0207	·0206	·0208	·0181	·0166	·0194
BELGAUM		·0118	·0120	·0133	·0153	·0173	·0178	·0173	·0168	·0166	·0158	·0130	·0118	·0149

359. The values of the "hygrometric quality" shown in this table are curved in figs. 755 to 758. In the curves for Mahableshwar, Poona, and Bombay we note the gradual decrease of hygrometric quality with increase of height in every month of the year, with average values for the year of ·0133, ·0146, and ·0183 respectively; and the curves of

Belgaum and Goa show the same decrease with yearly averages of ·0149 and ·0194. From this fact, that there is less vapour in a given quantity of air the higher we go, we may infer a probability that in this part of India the formation of clouds is, in the main, effected by condensation of vapour in rising currents of air. Comparing Kurrachee and Deesa, we also see that there is less vapour in the air inland than on the coast; and the same thing is shown in the comparison of Bombay and Goa with the Deccan stations; but here the decrease is mixed up with that due to height.

At the same place we see from the form of all the curves that the hygrometric quality is like the vapour pressure, high when the temperature is high and the wind from seaward, as during the monsoon months, and low when the temperature is low and the wind from landward, as during the winter months. We have remarked in paragraph 248 that about midwinter the north component of the wind, which is general over the low region from Lower Sind to further south than Bombay, vanishes at Goa. With this fact we have an interesting coincidence in the gradually increasing values of the hygrometric quality in the month of January as we proceed southward; at Deesa it is ·0087, at Bombay ·0135, and at Goa ·0164. It is doubtless due mainly to the dry northerly winds that the air of Bombay is so much drier than that of Goa; and the diurnal sea breezes to which Bombay is also subject at the same season, together with its higher temperature, sufficiently account for the air of Bombay being moister than that of Deesa.

Effect of Change of Level on the Temperature of a Body of mixed Air and Vapour.

360. Our next endeavour will be to find, with such rough approximation as is practicable, the quantities of energy that a grain of air, with its associated vapour, gives off and receives when it is lifted from a lower to a higher level, and when condensation of vapour takes place and rain is discharged in consequence of that lifting. The quantity of energy given off is the equivalent of the work done in expanding to the volume corresponding to the diminished pressure; and the quantity received is the latent heat (of change of state simply) of the vapour that is condensed. The latent heat of change of volume from the vapourous to the liquid condition will go to diminish the energy expended in expanding, and as we shall calculate the integral amount of work done between the initial and final conditions, the results will include the *ideal* contraction due to condensation of vapour.

361. Regnault's values of the total heat of steam at 0° centigrade and 100° C. are 606°·5 C. and 637°·0 C. respectively; these give for the total heat, at the temperature 22°·2 C., or 531°·1 of our scale, 613°·3 C., or for the total heat less the sensible heat, that is, the latent heat alone (613°·3 − 22°·2) = 591°·1 C. or 1064° Fahrenheit. The latent heat of change of state and change of volume together, set free when a grain of air at temperature 531°·1 of our scale is condensed, is sufficient then to raise the temperature of 1064 grains of water from the temperature 498°·2 to the temperature 499°·2; or, as the specific heat of air at constant volume is 0·1689, sufficient to increase the temperature of a grain of air by 6300°. Regnault's value of the total heat of steam for a given temperature refers to steam which has been evaporated from water at that temperature and against the corresponding pressure of vapour: hence the energy expended by a grain

of water in expanding to the volume of a grain of vapour at the same temperature will, neglecting the volume of the water in comparison with that of the vapour, be equal to the volume of the vapour multiplied by the vapour pressure (P); the volume of the vapour will be $\frac{29{\cdot}914}{\mathrm{P}} \frac{1}{{\cdot}6235}$ of the volume of a grain of air at temperature 491°·1: this latter is ·00177 cubic foot, and therefore the energy expended is

$$\frac{{\cdot}00177}{0{\cdot}6235} \cdot \frac{29{\cdot}914}{\mathrm{P}} \cdot \mathrm{P} = \frac{{\cdot}00177}{0{\cdot}6235} \times 29{\cdot}914 \text{ in foot-inches of mercury; or}$$

$$\frac{{\cdot}00177}{0{\cdot}6235} \times 29{\cdot}914 \times 3796{\cdot}7^{*} = 322°{\cdot}0 \qquad (63)$$

in degrees of temperature of a grain of air at constant volume; and this will be the same for all low values of P. This then is the latent heat of change of volume, and deducting it from 6300°, we obtain as the latent heat of change of state simply 5978°; that is to say, the heat liberated in the condensation of a grain of vapour is sufficient, besides compensating for the ideal work done by the surrounding air upon the vapour, to raise the temperature of 5978 grains of air one degree. This value applies to the temperature of condensation 531°·1, and it would be easy to find a function of the temperature which would be generally applicable, but the differences within the range of temperature that we have to deal with are small enough to allow, for the present, of our using the value 5978 throughout the range.

362. We require now to find the specific heat at constant volume of a grain of air *with* its associated vapour. The specific heat of steam at constant pressure is 0·4805; the work done by a grain of steam in expanding is to that done by a grain of air in expanding against the same pressure and for the same increment of temperature in the proportion of the two volumes, that is, as $\frac{1}{0{\cdot}6235}$ to 1; but the heat equivalent of the work done by a grain of air in expanding for one degree of temperature at constant pressure is $0{\cdot}1689 \times (\lambda - 1)$, hence that of a grain of vapour $= \frac{0{\cdot}1689 \times 0{\cdot}408}{0{\cdot}6235} = 0{\cdot}1105$; therefore, deducting this from 0·4805, we have for the specific heat of a grain of vapour at constant volume 0·3700. Hence, taking the mass of vapour from equation (61), the specific heat of a grain of dry air, together with its associated vapour, is

$$0{\cdot}1689 + 0{\cdot}3700 \times {\cdot}0012697 \frac{\mathrm{P}\,t\,\mathrm{T}}{p\,\mathrm{T} - \mathrm{P}\,t}, \qquad (64)$$

or in terms of the specific heat of a grain of dry air

$$1 + \frac{0{\cdot}3700}{0{\cdot}1689} \times {\cdot}0012697 \frac{\mathrm{P}\,t\,\mathrm{T}}{p\,\mathrm{T} - \mathrm{P}\,t} = 1 + {\cdot}002781 \frac{\mathrm{P}\,t\,\mathrm{T}}{p\,\mathrm{T} - \mathrm{P}\,t}, \qquad (65)$$

and, representing by $\left[\frac{\mathrm{P}\,t\,\mathrm{T}}{p\,\mathrm{T} - \mathrm{P}\,t}\right]$ the average of the two values of $\frac{\mathrm{P}\,t\,\mathrm{T}}{p\,\mathrm{T} - \mathrm{P}\,t}$ for the initial and final conditions that we consider in any given case, we may adopt, for the average ratio of the specific heats of a grain of air with vapour to that of a grain of air alone

$$1 + {\cdot}002781 \left[\frac{\mathrm{P}\,t\,\mathrm{T}}{p\,\mathrm{T} - \mathrm{P}\,t}\right]. \qquad (66)$$

* See definition, paragraph 278.

The latent heat of change of state of one grain of vapour being 5978°, that of M grains will be M × 5978; or from equation (61), the total latent heat of change of state of the vapour associated with a grain of dry air, is

$$\mathrm{M} \times 5978 = 5978 \times \cdot 0012697 \frac{\mathrm{P}\, t\, \mathrm{T}}{p\, \mathrm{T} - \mathrm{P}\, t} = 7 \cdot 5903 \frac{\mathrm{P}\, t\, \mathrm{T}}{p\, \mathrm{T} - \mathrm{P}\, t}, \tag{67}$$

and if the values of p, P, t, T at an elevated station be represented by accented letters the corresponding quantity for that station will be

$$7 \cdot 5903 \frac{\mathrm{P}'\, t'\, \mathrm{T}'}{p'\, \mathrm{T}' - \mathrm{P}'\, t'} \tag{68}$$

and the difference between (67) and (68) will be the latent heat of change of state, set free in consequence of the lifting of the air. If we now suppose the air surrounding the one grain considered to have been simultaneously lifted, there will be no tendency for the latent heat liberated to pass out from our one grain to the surrounding air, and it may be regarded as going to raise the temperature of that grain and of its associated vapour: hence, dividing by the relative specific heat of the mass of air and vapour,

$$\frac{7 \cdot 5903 \left\{ \frac{\mathrm{P}\, t\, \mathrm{T}}{p\, \mathrm{T} - \mathrm{P}\, t} - \frac{\mathrm{P}'\, t'\, \mathrm{T}'}{p'\, \mathrm{T}' - \mathrm{P}'\, t'} \right\}}{1 + \cdot 002781 \left[\frac{\mathrm{P}\, t\, \mathrm{T}}{p\, \mathrm{T} - \mathrm{P}\, t} \right]} \tag{69}$$

is the number of degrees which this mass will be raised in temperature by reason of the liberated latent heat of change of state.

363. To approximate to the amount of work done by the grain of air and its associated vapour, in expanding to the volume corresponding to the diminished pressure, we proceed as follows:—Reverting to paragraph 356 we see that the proportion of the whole volume of air and vapour occupied by dry air is $\frac{p - \mathrm{P}\frac{t}{\mathrm{T}}}{p}$; the remaining proportion $\frac{\mathrm{P}\frac{t}{\mathrm{T}}}{p}$ must therefore be occupied by the vapour; hence the ratio of the space occupied by vapour to that occupied by dry air is

$$\frac{\mathrm{P}\frac{t}{\mathrm{T}}}{p - \mathrm{P}\frac{t}{\mathrm{T}}} = \frac{\mathrm{P}\, t}{p\, \mathrm{T} - \mathrm{P}\, t}. \tag{70}$$

But the volume v of a grain of dry air, at pressure p and temperature t, is

$$v = \mathrm{V} \frac{t}{p}.$$

Hence the volume v' of a grain of dry air with its associated vapour is

$$v' = \mathrm{V}\, t \left\{ 1 + \frac{\mathrm{P}\, t}{p\, \mathrm{T} - \mathrm{P}\, t} \right\} \times \frac{1}{p}. \tag{71}$$

Now $\int p\, d\, v'$, the work done in expanding, depends, under the circumstances in question, chiefly upon p and its variations; we may therefore take $d\, v'$ with respect to p only, and substitute for the constant factors of the integral afterwards found a mean value of $\mathrm{V}\, t \left(1 + \frac{\mathrm{P}\, t}{p\, \mathrm{T} - \mathrm{P}\, t}\right)$, (say) the mean of the values at the two extreme elevations, or $\mathrm{V} \left[t \left(1 + \frac{\mathrm{P}\, t}{p\, \mathrm{T} - \mathrm{P}\, t}\right) \right]$. Thus differentiating (71)

$$dv' = -\mathrm{V}t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\frac{dp}{p}$$

$$p\,dv' = -\mathrm{V}t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\frac{dp}{p}$$

$$\int p\,dv' = -\mathrm{V}\left[t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\right]\log p$$

$$\int_{p}^{p'} p\,dv' = \mathrm{V}\left[t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\right]\log\frac{p}{p'}\text{ (in foot-inches of mercury),}$$

which, in degrees of a grain of dry air, becomes

$$3796{\cdot}7\,\mathrm{V}\left[t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\right]\log\frac{p}{p'}; \qquad (72)$$

or, dividing by the relative specific heat of a grain of dry air together with its associated vapour, we have

$$\frac{3796{\cdot}7\times{\cdot}0001078\left[t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\right]\log\frac{p}{p'}}{1+{\cdot}002781\left[\frac{\mathrm{P}t\,\mathrm{T}}{p\,\mathrm{T}-\mathrm{P}t}\right]} = \frac{0{\cdot}40928\left[t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\right]\log\frac{p}{p'}}{1+{\cdot}002781\left[\frac{\mathrm{P}t\,\mathrm{T}}{p\,\mathrm{T}-\mathrm{P}t}\right]} \qquad (73)$$

as the loss of temperature of the grain of air with its vapour, due to work done in expansion. Subtracting (69) from this we obtain

$$\frac{\frac{0{\cdot}40928}{0{\cdot}4343}\left[t\left\{1+\frac{\mathrm{P}t}{p\,\mathrm{T}-\mathrm{P}t}\right\}\right]\log_{10}\frac{p}{p'} - 7{\cdot}5903\left\{\frac{\mathrm{P}t\,\mathrm{T}}{p\,\mathrm{T}-\mathrm{P}t}-\frac{\mathrm{P}'t'\,\mathrm{T}'}{p'\,\mathrm{T}'-\mathrm{P}'t'}\right\}}{1+{\cdot}002781\left[\frac{\mathrm{P}t\,\mathrm{T}}{p\,\mathrm{T}-\mathrm{P}t}\right]} = \mathrm{X}-\mathrm{Y} \qquad (74)$$

as the total loss of temperature of the grain of air and associated vapour in rising to the higher level; the term X referring to the work done, and the term Y to the latent heat of vapour set free.

364. Obtaining from Table 157 data for the calculation of this quantity, with reference to the pairs of stations Bombay and Poona, Bombay and Mahableshwar, and Goa and Belgaum, and placing beside the calculated quantity in each case the actual diminution of temperature, we find that in the respective months the theoretical diminution of temperature (D) exceeds the actual (d) by the quantities shown in columns 6, 11, and 16 of the following table.

TABLE 158.

Months.	Bombay and Poona.					Bombay and Mahableshwar.					Goa and Belgaum.				
	X	Y	D	d	D−d	X	Y	D	d.	D−d	X	Y	D	d	D−d
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	14·6	14·4	+ 0·3	+2·2	− 1·9	32·5	19·8	+12·7	+ 9·3	+ 3·4	17·3	26·9	− 9·6	+10·4	−20·0
February	14·7	15·4	− 0·7	−0·6	− 0·1	32·5	16·4	+16·1	+ 6·2	+ 9·9	17·4	30·0	−12·7	+ 7·5	−20·2
March	14·8	23·0	− 8·2	−2·3	− 5·9	32·6	25·6	+ 7·0	+ 5·5	+ 1·5	17·5	31·6	−14·1	+ 5·3	−19·4
April	14·9	27·8	−13·0	−3·2	− 9·8	32·7	32·6	+ 0·2	+ 5·8	− 5·6	17·5	29·9	−12·3	+ 4·9	−17·2
May	14·9	25·1	−10·2	+0·5	−10·7	32·7	30·8	+ 1·9	+11·1	− 9·2	17·5	22·3	− 4·8	+ 7·2	−12·0
June	14·7	24·2	− 9·5	+4·4	−13·9	32·6	34·3	− 1·7	+17·0	−18·7	17·4	21·4	− 4·0	+ 8·1	−12·1
July	14·6	22·2	− 7·6	+4·9	−12·5	32·7	32·7	0·0	+16·2	−16·2	17·4	21·4	− 4·0	+ 8·8	−12·8
August	14·7	20·6	− 5·9	+5·2	−11·1	32·7	32·1	+ 0·6	+15·7	−15·1	17·3	22·3	− 5·0	+ 9·3	−14·3
September	14·7	20·2	− 5·5	+4·7	−10·2	32·7	31·5	+ 1·2	+15·8	−14·6	17·2	23·0	− 5·8	+ 8·9	−14·7
October	14·6	24·3	− 9·7	+3·9	−13·6	32·5	36·5	− 4·0	+14·2	−18·2	17·2	28·5	−11·3	+ 8·8	−20·1
November	14·6	21·1	− 6·6	+4·0	−10·6	32·8	32·2	+ 0·6	+13·5	−12·9	17·3	29·3	−12·0	+10·5	−22·5
December	14·5	19·8	− 5·3	+4·7	−10·0	32·6	29·4	+ 3·2	+12·2	− 9·0	17·3	27·9	−10·7	+11·6	−22·3
Year	14·7	21·5	− 6·8	+2·4	− 9·2	32·6	29·4	+ 3·0	+11·9	− 8·9	17·4	26·1	− 8·8	+ 8·5	−17·3

The temperatures in this table, it need hardly be mentioned, are expressed in degrees of the grain of air with its associated vapour at constant volume.

365. It may, at first sight, seem that, there being no rainfall during the greater part of the year, the calculations for the dry-weather months have no connection with the hypothetical rising of a body of moist air which we have been dealing with. But, as in all seasons, water in the form of haze or clouds is probably always, and certainly often, present in the lower atmosphere, the converse process of the falling of a body of air would be attended, first, by an increase of temperature following the rate of the ultimate law; and, secondly, by the abnormally high temperature thus acquired disappearing in the evaporation of some of the cloud matter in the course of the fall. Whether a stream of moist air flowed up or down a mountain side, we should therefore expect that the change of temperature would be of less amount than that given by the ultimate law as the equivalent of the actual changes of pressure, and leaving out of account the change of hygrometric quality of the air. Comparing in the last table the columns headed "X" with the columns headed "*d*," we see that this is, in all seasons, and with respect to each pair of stations, very decidedly the case; and hence we may infer, conversely, that if superficial rising and falling currents do actually flow one way or the other, condensation of vapour takes place in rising, and evaporation of it in falling, at all seasons. This argument proceeds on the assumption that the body of air which constitutes the lowermost layer at the initial station constitutes also the lowermost layer at the final station; but unless there were mixture of the flowing current, in its course, with the air above it, and that to a considerable extent, the inference would not be materially influenced if the assumption were not true.

366. During the winter months the winds blow with much persistency from landward to seaward both in the Deccan and in the Konkan, and if these motions be in continuation one of the other the flow of air will be down the slopes of the Ghauts. But the theoretical change of temperature—supposing the excess vapour found with the air at the lower station to have been evaporated on the route between the two stations—is generally in the direction of too great coolness at the lower station, and very much so. The only cases of too great warmth at the lower station are January, February, and March in the comparison of Bombay and Mahableshwar, and in the last month the coast winds have ceased to be from landward.

367. Considering now the invariable persistency, during the monsoon, of west or south-west winds along the whole line of the Konkan, on the Deccan to eastward of that line, and at stations here and there on the Western Ghauts, it is difficult to suppose that the stream found to be flowing above the Ghauts is not a continuation of that which is observed below; and that, therefore, the same body of air which is found below is not lifted along the slopes of the Ghauts up to the higher level of the Deccan plateau, flowing of course over the ridge of the Ghauts along its whole length. Here then at this season, if anywhere at any time, we should expect the cooling effect of the expansion of the air, and the heating due to liberated latent heat of vapour, to be apparent in the relative temperatures of low and high stations. But the table shows that the combined theoretical effect of these actions is to make the higher station the warmer, both in the comparison between Bombay and Poona, and Goa and

Belgaum, and that Mahableshwar should never be more than 1°·2 cooler than Bombay; results which are far from being consistent with the facts. What then has become of the liberated latent heat which does not appear in the temperature of the air of the upper stations? For this we have not far to seek. For just as the addition of radiant heat to a portion of a column of air causes topsy-turvy movements which carry the heat upward in the column, so will the liberation of latent heat produce the same effect, unless indeed the heat liberated in the next higher portion be as great as that liberated in the same time in any portion considered. And this is not likely, seeing that the absolute quantity of vapour associated with a given quantity of dry air diminishes, after condensation once begins, at every succeeding upward step. Hence we imagine that during the formation of raindrops in a body of ascending air, heat is being transferred and air with it to the strata of air above it, which heat is therefore no longer present in the bottom stratum in the state in which it reaches the upper observing station. Another reason why this should be so may be inferred from the following sequence of phenomena: (1) there is increased condensation as the Ghauts are approached from the coast (see paragraph 342); (2) thereby a lateral increase of temperature will be set up in the same direction, in consequence of the unequal liberation of latent heat; and (3) local convection currents will be established, superimposed upon the general monsoon current, and carrying upward some of the heat set free.

368. It is quite certain then from what has been said in the last two paragraphs that although during the monsoon there may be a transfer, along the ground surface, of air from the Konkan to the Deccan, there is no *complete* reverse transfer during the winter months. A reason may be found for this in the conservative influence arising from the circumstance that the actual rate of decrease of temperature with decrease of barometric pressure in rising in the atmosphere is very much in defect of the rate given by the ultimate law. In consequence of this defect a body of air in rising becomes abnormally cold, and in falling becomes abnormally hot in comparison with the air of the changed position which it has reached, and a tendency to fall back, by reason of its excess density, is thus developed in the rising body, and a tendency to rise back, by reason of its defect of density, in the falling body. We conclude then, that although the surface flow of air must to some extent have place, and be accompanied by the corresponding changes of temperature due to expansion or contraction and to latent heat set free or absorbed, the actual motions that take place are of too complex a character to admit of even an approximate explanation of the relative temperatures at different heights on so simple a hypothesis as that which we have been considering. At the same time we remark that in the actual temperature relations of Deccan and Konkan stations during the monsoon, there is nothing inconsistent with the supposition that the deposition of vapour, and consequent fall of rain, is a consequence of the cooling of the air produced by its expansion in rising.

The Dynamical Problem of the Determination of Heights by means of Observations of Barometric Pressure.—Discrepancies and their probable Explanation.

369. We have now to call attention to the problem of the determination of heights by means of observations of barometric pressure, and especially to advantages that seem to

attach to the treatment of the question as a dynamical rather than a statical one, both as securing greater accuracy in the practical result and as suggesting truer conceptions of the physical conditions involved.

It will be convenient first to find a formula—using the nomenclature that we have hitherto employed—connecting the barometric pressures at the top and bottom of a vertical column of air, on the assumption that the air in the column is at rest. We shall have to apply it only up to heights of less than 4,500 feet, and we may neglect to take account of all small corrections that would affect the height by less than a single foot. Let the area of the horizontal section of the column be one square foot, and let z be the height above mean sea level of a layer of the column the thickness of which is dz, then the difference of pressure between the bottom and top surfaces of this layer is

$$-g\rho\,dz \qquad (75)$$

in units of mass, acted on by the unit force, on the unit surface. In inches of mercury, acted on by gravity, on the square foot of surface, this becomes

$$dp = -\frac{\rho\,dz}{495088}. \qquad (76)$$

Equation (62) gives the density of the atmosphere in the latitude of London, 565·0862 grains being the weight of a cubic foot of air under the pressure of 29·914 inches of mercury, at the temperature 32° Fahrenheit, and acted upon by the force of gravity in London. The ratio of the force of gravity at the sea level in Bombay to that of London is

$$\frac{1 - \cdot00259\cos 2(18°\ 53'\ 45'')}{1 - \cdot00259\cos 2\,(51°\ 28'\ 39'')} = 0{\cdot}99738 = \frac{g}{G}\ (\text{say}); \qquad (77)$$

hence the same absolute pressure which is represented by 29·914 inches of mercury in London will be represented by $\frac{29{\cdot}914}{0{\cdot}99738} = 29{\cdot}993$ inches of mercury in Bombay. Thus we see that to render equation (62) generally applicable we must multiply the right side by $\frac{g}{G}$, when

$$\rho = 565{\cdot}0862\,\frac{g}{G}\left[\frac{p}{29{\cdot}914}\left\{\frac{491{\cdot}1}{t} - \frac{P}{p}\left(\frac{491{\cdot}1}{T} - \cdot6235\right)\right\}\right], \qquad (78)$$

inserting which in (76) we obtain

$$\frac{dp}{p} = -\frac{565{\cdot}0862}{495088 \times 29{\cdot}914}\,\frac{g}{G}\left\{\frac{491{\cdot}1}{t} - \frac{P}{p}\left(\frac{491{\cdot}1}{T} - \cdot6235\right)\right\} dz. \qquad (79)$$

Attributing now to the top of the column considered the same conditions as are found at an upper station of observation, necessarily laterally displaced, we have in experimental integrations of this expression used for t the function of p represented by equation (14), (paragraph 292), and we have made $\frac{P}{p}$ vary in geometrical progression as z varies in arithmetical progression, and in such a manner that $\frac{P}{p}$ has the observed values at the limiting heights; but the results differ scarcely appreciably from those which are obtained much more simply on the assumption that for the expression

$$\left\{\frac{491{\cdot}1}{t} - \frac{P}{p}\left(\frac{491{\cdot}1}{T} - \cdot6235\right)\right\}$$

may be substituted, and treated as a constant quantity, the mean of the two values of it deduced from observed data at the limiting heights. Representing this mean by

$$\left[\left\{\frac{491\cdot1}{t}-\frac{P}{p}\left(\frac{491\cdot1}{T}-\cdot6235\right)\right\}\right],$$

and adopting the last-named assumption for the reason stated, equation (79) becomes

$$\frac{dp}{p}=-\frac{565\cdot0862}{495088\times29\cdot914}\frac{g}{G}\left[\left\{\frac{491\cdot1}{t}-\frac{P}{p}\left(\frac{491\cdot1}{T}-\cdot6235\right)\right\}\right]dz, \tag{80}$$

and integrating

$$\log_\epsilon p=-\frac{565\cdot0862}{495088\times29\cdot914}\frac{g}{G}\left[\left\{\frac{491\cdot1}{t}-\frac{P}{p}\left(\frac{491\cdot1}{T}-\cdot6235\right)\right\}\right]z. \tag{81}$$

Taking now the definite integral, using unaccented letters for the lower and accented letters for the upper station, we have

$$\log_\epsilon\frac{p}{p'}=\frac{565\cdot0862}{495088\times29\cdot914}\frac{g}{G}\left[\left\{\frac{491\cdot1}{t}-\frac{P}{p}\left(\frac{491\cdot1}{T}-\cdot6235\right)\right\}\right](z'-z), \tag{82}$$

and using for g, as near enough for all the cases we have to deal with, its value at Bombay, and changing to common logarithms

$$\log_{10}\frac{p}{p'}=\frac{565\cdot0862\times0\cdot99738\times\cdot4343}{495088\times29\cdot914}\left[\left\{\frac{491\cdot1}{t}-\frac{P}{p}\left(\frac{491\cdot1}{T}-\cdot6235\right)\right\}\right](z'-z) \tag{83}$$

$$=\frac{(z'-z)}{60503}\left[\left\{\frac{491\cdot1}{t}-\frac{P}{p}\left(\frac{491\cdot1}{T}-\cdot6235\right)\right\}\right]. \tag{84}$$

Laplace's value of the constant factor in this expression is $\frac{1}{60282}$

$$\left(=\frac{1-\cdot00259\cos(37^\circ\,47'\,30'')}{60159}\right),$$

and this value has been used in the calculations that we have made. Depending on older determinations of the relative densities of air and mercury, it is less accurate than the value which appears in equation (84); but as our principal purpose is to compare the differences, at different seasons, between the theoretical and the actual pressures at the upper one of two fixed stations, the relation between one difference and another will not be sensibly affected by the small error in question.

370. Using then instead of equation (84) the following

$$\log_{10}\frac{p}{p'}=\frac{z'-z}{60282}\left[\left\{\frac{491\cdot1}{t}-\frac{P}{p}\left(\frac{491\cdot1}{T}-\cdot6235\right)\right\}\right] \tag{85}$$

and the values of p, t, P, and T given in Table 157, we have first calculated $(z'-z)$ from the mean values of p, t, P, and T for the year; and then, inserting the value found, together with the mean observed values of p, t, P, T, t', P′, and T′, have calculated for each month a value of p', which we call the theoretical value; and applying this process for the pairs of stations Bombay and Poona, Bombay and Mahableshwar, and Goa and Belgaum, we have obtained for the respective approximate differences of height 1,956 feet 4,331 feet, and 2,305 feet; and for the theoretical values of p' the numbers shown in the next table.

TABLE 159.

Pair of Stations.	Values of p'.			Values of p'.			Values of p'.			Values of p'.		
	Theoretical.	Observed.	Observed *minus* Theoretical.	Theoretical.	Observed.	Observed *minus* Theoretical.	Theoretical.	Observed.	Observed *minus* Theoretical.	Theoretical.	Observed.	Observed *minus* Theoretical.
	January.			February.			March.			April.		
Bombay and Poona	27·956	27·977	+·021	27·936	27·944	+·008	27·909	27·903	−·006	27·867	27·847	−·020
Bombay and Mahableshwar	25·692	25·726	+·034	25·684	25·713	+·029	25·676	25·682	+·006	25·650	25·637	−·013
Goa and Belgaum	27·398	27·409	+·011	27·379	27·385	+·006	27·365	27·350	−·015	27·325	27·303	−·022
	May.			June.			July.			August.		
Bombay and Poona	27·829	27·796	−·033	27·725	27·714	−·011	27·711	27·717	+·006	27·767	27·763	−·004
Bombay and Mahableshwar	25·614	25·600	−·014	25·501	25·494	−·007	25·480	25·457	−·023	25·529	25·508	−·021
Goa and Belgaum	27·297	27·271	−·026	27·230	27·224	−·006	27·231	27·225	−·006	27·257	27·258	+·001
	September.			October.			November.			December.		
Bombay and Poona	27·822	27·816	−·096	27·881	27·888	+·007	27·939	27·961	+·022	27·959	27·987	+·028
Bombay and Mahableshwar	25·579	25·560	−·019	25·640	25·656	+·016	25·686	25·678	−·008	25·700	25·724	+·024
Goa and Belgaum	27·285	27·295	+·010	27·314	27·332	+·018	27·369	27·382	+·013	27·392	27·409	+·017

371. If the theory were complete, the theoretical and observed values of p' should be alike for each month, as our process makes them necessarily for the average of the year. We see, however, that the differences shown in the third column of each monthly set are very considerable; and we conclude that the statical theory is, to the extent of those differences, at least, imperfect.*

372. A sensible, though possibly but a small portion of these discrepancies may be explained, without modifying any of the conditions of the problem, further than to take into account the fact that the portion of the atmosphere intervening between the observing stations is always in a state of motion. As we are precluded, by lack of observed data, from dealing with any actual case, we may choose for consideration the simple case in which the wind blows continuously, but with varying velocity, from the lower station directly towards the higher one; and, for the further sake of simplicity, we may suppose the same body of air to flow along a channel, that may have vertical sinuosities and be of varying sectional area, without at any point having any motion in a direction athwart the channel; also we may suppose that no rotatory motion of the air in the channel is

* It is true that the barometric data used are for the mean of the 24 hours of the day, only for Bombay, Poona, and Belgaum, whilst those of Mahableshwar are for the hours 6 and 16, and those of Goa for the hours 9, 12, 15, and 21; and it is conceivable that the diurnal inequalities for the mean hour of observation at the two latter stations may not be exactly the same all the year round. Unless, however, they vary more than at Bombay, which is very improbable, the differences in Table 159 for Goa and Belgaum would be scarcely at all affected by allowance for the variation, and those for Bombay and Mahableshwar only to the extent of ·005 inch in the worst case.

Difference of barometric gradient of a more persistent kind—as holding in the average of a month, and due to the lateral distance of the stations—is, in effect, what is considered in the next seven paragraphs; and it is shown that the winds which actually blow are much too feeble to consist with the simultaneous existence of gradients of the magnitude required by the differences in Table 159.

generated between the two stations, and that the motion at every part of the channel is steady.

373. Let us take p, u, z, s, $\varkappa$, and ρ for the barometric pressure, velocity along the channel, vertical height, distance along the channel from the lower station, area of the transverse section of the channel, and density of the air respectively, at a point of the channel at which the conditions are considered; and for corresponding quantities at the lower and upper stations U, Z, and U′ Z′; also let t represent the time. Since the motion is steady the equation of motion is*

$$\frac{1}{\rho}\frac{dp}{ds} = -g\frac{dz}{ds} - \frac{Du}{Dt} = -\left(g\frac{dz}{ds} + \frac{du}{ds}\cdot\frac{ds}{dt}\right) = -\left(g\frac{dz}{ds} + u\frac{du}{ds}\right), \tag{86}$$

and the equation of continuity is

$$\frac{d}{ds}(\kappa\rho u) = 0 = \frac{1}{u}\frac{du}{ds} + \frac{1}{\rho}\frac{d\rho}{ds} + \frac{1}{\kappa}\frac{d\kappa}{ds}; \text{ whence} \tag{87}$$

$$u\frac{du}{ds} = -\left(\frac{u^2}{\rho}\frac{d\rho}{ds} + \frac{u^2}{\kappa}\frac{d\kappa}{ds}\right), \tag{88}$$

inserting which in equation (86) we obtain

$$\frac{1}{\rho}\left(\frac{dp}{ds} - u^2\frac{d\rho}{ds}\right) = \frac{1}{\rho}\frac{dp}{ds}\left(1 - u^2\frac{d\rho}{dp}\right) = -g\frac{dz}{ds} + \frac{u^2}{\kappa}\frac{d\kappa}{ds}. \tag{89}$$

374. Now the monsoon stream of air, after passing the coast of the Konkan, would, if it were of constant density, on meeting the obstacle formed by the Western Ghauts, and being lifted above that obstacle, be contracted, so that the area of the transverse section of every elementary channel which forms a part of the whole stream would be diminished; but on the other hand the diminishing density of the rising air increases the transverse section of the elementary channels; hence, to take a case for trial, we may, in the absence of observed data, suppose the counteracting tendencies to balance each other, and $\varkappa$, therefore, to be constant.

Let us note too that in the atmosphere we have approximately

$p = k\rho$, where k is a constant

$\therefore \frac{d\rho}{dp} = \frac{1}{k}$, and assuming κ to be constant, equation (89) becomes

$$\frac{1}{\rho}\frac{dp}{ds}\left(1 - \frac{u^2}{k}\right) = -g\frac{dz}{ds} \tag{90}$$

$$\frac{dp}{p} = -\frac{\rho}{p}g\,dz\left(\frac{1}{1 - \frac{u^2}{k}}\right). \tag{91}$$

Now the first factor of the right-hand member of this equation is the value of $\frac{dp}{p}$ given by the statical theory; and therefore the integral of the right-hand member will be equal to the integral given by that theory $\left(= -\int\frac{\rho}{p}g\,dz\right)$, divided by some value of $\left(1 - \frac{u^2}{k}\right)$ intermediate between the greatest and least values that occur in a continuous progress from the lower end to the upper end of the channel. For u in this divisor we may take for

* See Besant's "Hydromechanics," second edition, article 122.

trial the mean of its values at the two stations; and, to find k, we have at temperature 32° Fahrenheit, and under pressure 29·914 inches of mercury (at 32° Fahrenheit), the density of air in terms of that of water $= \frac{565 \cdot 086}{436972}$, that of mercury being 13·598: hence

$$p = g \times 13 \cdot 598 \times \frac{29 \cdot 914}{12} = k\rho = k \times \frac{565 \cdot 086}{436972}, \text{ whence}$$

$$k = 843988, \text{ and} \tag{92}$$

$$1 - \frac{\left(\frac{U + U'}{2}\right)^2}{k} = 1 - \frac{\left(\frac{U + U'}{2}\right)^2}{843988} \tag{93}$$

in which the velocity is expressed in feet per second.

As a velocity of one mile per hour = 1·46 feet per second, if V, V′ be the velocities of the wind at the lower and upper stations in miles per hour,

$$U = 1 \cdot 46\, V; \left(\frac{U + U'}{2}\right)^2 = 2 \cdot 151 \left(\frac{V + V'}{2}\right)^2, \text{ and}$$

$$1 - \frac{\left(\frac{U + U'}{2}\right)^2}{843988} = 1 - \frac{2 \cdot 151}{843988}\left(\frac{V + V'}{2}\right)^2 = 1 - \frac{\left(\frac{V + V'}{2}\right)^2}{392350}. \tag{94}$$

375. Hence, to correct for the effect of the variable velocity of the wind, we must, when the difference of height is given to find $\log \frac{p}{p'}$, increase the result given by the statical theory by $\frac{\left(\frac{V + V'}{2}\right)^2}{392350}$ of its own value; and, when the difference of pressure is given to find the difference of height, decrease the result given by the statical theory by $\frac{\left(\frac{V + V'}{2}\right)^2}{392350}$ of itself. With a wind of mean velocity 20 miles per hour, and a height of 4,500 feet, the correction of the difference of pressure amounts to + ·005 inch; with a mean velocity of 50 miles, and height of 10,000 feet, it would be nearly + ·06 inch. These results are for the hypothetical case in which $d\varkappa = 0$, and therefore the sign of $d \cdot u$ is positive when the stream ascends; but setting aside other conditions than the simple obstruction of an otherwise free flow of air, it is easily seen that $\frac{d\varkappa}{\varkappa}$ approaches only but does not reach the limit $\frac{d\rho}{\rho}$ till the obstruction has been left some distance behind, and that therefore $d\,u$ will still retain the positive sign for an ascending portion of the stream. Hence we may expect to find the pressures along the monsoon current affected in the same direction, though not to the same extent, as in our hypothetical case.

376. It is scarcely needful to remark that longitudinal motion of the air in the channel, unaccompanied by variation of the section of the channel, or of the density of the air, would produce no effect in modifying the statical pressures; but our assumption of a channel of constant section with a varying density of the air involves also a varying velocity of motion along the channel.

377. Motion of the air down such a channel as we have been considering from the upper to the lower station would, under the same restricted conditions, and for the same

numerical velocities, cause the difference between the top and bottom pressures to be of greater magnitude than that given by the statical theory in the same proportion as when the air flows the reverse way. The only changes in the correcting factors are the substitution of $-$ V for V, and of $-$ V′ for V′, which does not affect the value of the factor.

378. We have seen reason (in paragraphs 366 to 368) for believing that the easterly surface winds of the Deccan plateau in the winter months do not completely follow the declining ground surface to the ground level of the Konkan; and it is reasonable to suppose that the continuous surface flow *up* the mountain sides is much more complete during the monsoon, when continuance along a level course is impossible, than is the flow *down* the mountain sides during the winter, when such continuance in a westward direction is the most natural thing to look for. If this be so, the actual differences of pressure between a low and a high station should exceed the differences given by the statical theory in greater degree during the monsoon than in the winter months; or what comes to the same thing, the excess of the observed values of p' above the theoretical values in Table 159 should be less during the monsoon months than in the winter. Comparing the differences in the third column of each set for the months June to September with those of the months December to February, we see that this is decidedly the case with respect to each pair of stations. From this we conclude not only that more accurate determinations of heights would be obtained by observing the velocity and directions of the wind at the two stations, and using the dynamical equation in preference to the statical equation, but also that there is a difference in the extent of the partial transfer of air from one station to the other, in the cases considered, in the monsoon and winter months. It should be noted, however, that these conclusions depend on the accuracy of our assumption that the velocity of the wind is greater at the elevated than at the coast stations, from westward during the monsoon, and from eastward during the winter months; an assumption which as regards the winter months we have already seen to be probably correct, but which as regards the monsoon must await further observation for its confirmation.

379. Having gone so far in search of an explanation of the discrepancies in question, and finding that they were still in a great measure unremoved, noticing also that they lie in the direction indicating too great a density of the air intervening between the two stations in the monsoon months as compared with the winter months, that is, after due allowance is made for temperature and pressure, it occurred to the writer that this might be due in some way to the particles of water suspended in the air in the shape of cloud matter or raindrops; and further consideration, together with results of experiment, has led him to regard it as highly probable that liquid or solid particles suspended in the atmosphere do indirectly exert a pressure which affects the barometer. He remembers also that, in the year 1870, Mr. W. W. Rundell, Secretary to the Underwriters' Association, Liverpool, mentioned to him in conversation an experiment which he had made apparently with the object of testing this very point. To the best of the writer's recollection, Mr. Rundell put a quantity of fine sand into a vessel, which was then partially filled with water. A bottle floated in the water with its neck protruding above the surface of the water; and it was found that on stirring up the sand the bottle neck rose further out of the water, and gradually fell again as the sand subsided; evidently showing that a greater fluid pressure was exerted on the bottle when the

sand was in suspension than when it all lay at the bottom of the vessel. This experiment the writer has repeated, substituting a hydrometer for the bottle, and fine soft red soil—obtained by collecting the upper portions of sediments of the soil in water—for the fine sand, and using for the vessel a tall cylindrical glass jar. The results of this experiment were decidedly and invariably the same as were found by Mr. Rundell.

380. The statical theory takes account of the pressure exerted by water in the atmosphere in the state of vapour, but as soon as the vapour becomes condensed, treats it like an equal volume of air; a procedure which would be quite correct if the particle of condensed vapour forthwith fell to the ground with the accelerating velocity that it would acquire if a vacuum took the place of the atmosphere. There can be no doubt, however, that in fact cloud matter often actually rises in the air, nor that raindrops fail to acquire on reaching the ground anything like the velocity due to the height from which they have fallen. The explanation generally given of these phenomena is, first, that, relatively to the air which immediately surrounds it, cloud matter is really falling, but that both it and the air about it form part of an ascending current of greater upward velocity than the relative downward velocity of the cloud; and, secondly, that the resistance of the air causes the falling raindrop quickly to acquire a maximum, or rather a diminishing, velocity. The *normal* condition of water in the atmosphere, whether as cloud or raindrops, is generally admitted to be one of descent with a practically uniform velocity. In this state the writer conceives the resistance of the air, which must balance the downward acceleration of gravity acting on the water particle or drop, to be only a name for the aggregate of the equivalent energies or pressures brought forth; and these will be of two kinds—(1) The motion of rotation of particles of air caused by friction of the moving drop of water, which rotation will be quickly converted into heat; and (2) the downward motion of translation of the stream of air which follows the falling drop,—this being the complementary effect of the friction of the two substances. Now, by friction against the still air, the latter motion will be to some extent distributed to surrounding air, and be gradually destroyed by the reaction of the air below upon the moving particles. But such a reaction cannot have place generally and continuously over a large surface in the upper atmosphere without increasing the barometric pressure below; and yet when rain is falling extensively and persistently, the drops must be so rank and extend through so great a depth of the atmosphere as to give some degree of generality to the reaction in question.

381. Thus we infer that the falling rain which during the great proportion of the monsoon time occupies the stratum of air intervening between our Konkan and Deccan stations increases the effective density of the air, and causes a larger difference of pressure to be observed between low and high stations than would be the case if the strata were filled with dry air and vapour only of the observed densities; and the difference of these, together with other smaller effects, between January and July amounts in the comparison between Bombay and Mahableshwar to as much as ·057 inch of pressure.

If this view be correct, the large negative differences shown in Table 159 in the comparison between Bombay and Poona, and Goa and Belgaum for the months April and May seem to imply that the effective pressure of cloud matter in the lower atmosphere in those months is much greater than that of raindrops during the monsoon. A reason why

this should be so, may be found in the fact that the mass of an average raindrop being large in comparison with that of a cloud particle, the maximum falling velocities will be similarly related, and so in the raindrop a much greater proportion of the acceleration of gravity upon it will be absorbed in the production of heat and undestroyed motion in the air, and less left to be effective as pressure, than in the cloud particle. This explanation is also consistent with the observed deficiency of density of the lower atmosphere in the winter months as compared with April and May, for the winter are the least cloudy months of the year, as will be seen by consulting Table 115. By deficiency of density we mean here the deficiency still remaining after allowance according to the statical theory for the differences of pressure, temperature, &c.

382. It may be remarked here that the portion of the acceleration of gravity upon a falling raindrop, which appears in the form of a downward current of air following the drop, will depend largely upon the extent of the rain clouds of which the drop forms an element, and on the position of the drop amongst these clouds. The current in front of a solitary drop would find a ready lateral outlet along its whole course, and the following current would therefore be considerable, and would flow outward laterally near the ground; and thus we find that a rapid formation of rain in a cloud region of small extent is accompanied by surface winds (squalls) of great velocity blowing in all directions from the region under the cloud. This radiating of squall winds is inferred from the fact, frequently observed both at sea and on land, that the winds blow from the direction of the storm cloud. The first effects of an extensive rain storm will, in like manner, be to produce winds blowing outward from the borders of the storm region. But a cumulative counteracting tendency is brought out from the commencement of the formation of rain, first, by the fall of the barometer caused by the removal of a part of the matter constituting the atmosphere of the storm region, and the consequent inflow of air from beyond the borders of the storm; and, secondly, by surface convection currents blowing inwards by reason of the increased temperature of the storm region due to liberated latent heat of vapour. Herein we find a connecting link also between those theories of cyclones which attribute the inflow of the observed winds, in the one case to a depression of barometer caused by the rainfall, and in the other to the meeting and ascent of moist currents of air whose directions of motion are, before meeting, in some degree opposed to each other. The nucleus of a cyclone is formed wherever rain begins to form and fall, for a lateral difference of temperature is established and convection currents generated, which either quickly equalize the temperature of the rain district and surrounding regions, or develop into cyclones, according as the rainy district is not or is surrounded, or partly surrounded, by districts whose surface air is moist enough to become condensed at the height to which it will be lifted as part of the circulating current. The stream lines of the convection currents will have greater upward motion the nearer they are to the nucleus, and thus more condensation will take place the nearer a place is to the nucleus, and the pre-existing lateral increase of temperature inward will be exaggerated. The cyclone will therefore grow in extent and intensity till the heat carried away from the central region by the circulating currents, and which is in some measure brought down to the surface again at the borders of the storm, begins to cause a decrease in the rate of lateral increase of temperature inward; and from this time the storm will decay. If, however, the surface air which flows in on one side of the nucleus is more moist than the air on other sides, more

latent heat will be liberated on that side, the air of which will thus become warmer than that of the nucleus; and the centre of the storm will be transferred in the direction of its most moist side. Thus the centre of a cylone will travel along a track which at all points of its course is towards that side on which the rainfall is heaviest. On account of the curvature of the inflowing currents caused by the earth's rotation, this side will not necessarily be the side from which the most moist air started on its inward course; but as we are not sketching a complete theory of cyclones, but only pointing out a modification of the mode of reaching the results of current theories which the convection current notion seems to render necessary, and drawing attention to points which this notion explains and current theories do not, we need not pursue this matter.

383. There is one other point, however, which we ought not to pass over in silence. It might, at first glance, be presumed that the low barometric pressure in the middle of a cyclone was due partly to the collapse of the vapour in condensing, the surrounding air expanding to occupy space thus left vacant, but this is not the case; for the latent heat given up by a condensing particle of vapour causes the air associated with the particle to expand to a greater volume than, before condensation, was occupied by the air and vapour together. We have seen (paragraph 361) that the heat liberated by the condensation of a grain of vapour is about sufficient to raise the temperature of a grain of dry air at constant volume 5978°; hence it will raise the same grain of air at constant pressure $\frac{5978}{1\cdot408} = 4246°$. If a small fraction of a grain (a) of the vapour associated with a grain of dry air be condensed it will raise the temperature of the air—disregarding the remaining vapour—$4246° \times a$. This will increase the volume of the grain of air in the proportion of 1 to $1 + \cdot00204 \times 4246 \times a$; whilst the removed vapour had a proportion to the whole volume of only $\frac{a}{\cdot6235}$ to 1. Hence the total volume after the condensation will be $1 + a\left(\cdot00204 \times 4246 - \frac{1}{6235}\right) = 1 + 7\cdot058 \times a$, which is greater than the original volume. But the topsy-turvy movements or convection currents, which follow the receipt by the air of an increment of heat, prevent the abnormality of volume from becoming of sensible degree.

384. Similar conditions to those which we have described as creating a lateral increase of temperature from the borders towards the centre of a cyclone may be advanced as reason why in the approach, during the monsoon, from the coast of the Konkan to the ridge of the Ghauts, local convection currents should be established, being superimposed on the general monsoon current, and enhance the lifting and rain-forming tendencies by exaggerating the upward course of the stream lines. We may remark also, that as the topsy-turvy movements, which result from the liberation of latent heat, carry air upward, they also constitute cloud-forming and rain-forming actions.

385. Even at the birth of a storm the current which follows a falling drop in the midst of extensive rain clouds will be very slight, because it finds its outlet barred by tendencies to the formation of similar currents on all sides of it; and thus a corresponding excess of barometric pressure will result from the action of gravity on a raindrop in such a position as compared with that of a drop on the edge of the storm.

386. The writer has still to perform the agreeable duty of acknowledging his obligations to those who have assisted him in a work of great magnitude, of which the results only appear in the foregoing memoir. To Mr. F. Chambers he is indebted for the direction, jointly with himself, of computations and compilation processes, for the construction of all the maps, and for a careful revision of the work, for several valuable suggestions for its improvement, and generally for a free communication of his ideas on the subjects discussed in it. Mr. Vinayek Narayen has been of great service in the immediate supervision of the computers, himself performing many of the more difficult operations; his intelligence and orderly habits have enabled him readily to command, at all times, the resources of the computing room; a most valuable faculty, in one holding his position, at a time antecedent to the systematic indexing and binding together of the many and various calculation papers. Mr. Hurry Chintaman, Mr. Purshram Luxuman, and Mr. Vishnoo Damodher have all worked assiduously and intelligently to perform the parts allotted to them. To Mr. Purshram has been allotted the task, amongst others, of copying the rough manuscript of the work, and to Mr. Vishnoo, jointly with Mr. Vinayek, the construction of diagrams and curves.

Altogether the writer regards himself as very fortunate in having been able to procure and train so capable a body of assistants; for without efficient aid in mechanical processes, and even in somewhat higher ones, a work of this character is utterly beyond the powers of the most assiduous student.

APPENDIX.

ALPHABETICAL LIST of STATIONS marked on the Map accompanying "THE METEOROLOGY OF THE BOMBAY PRESIDENCY, by CHARLES CHAMBERS, F.R.S.," with approximate Latitudes and Longitudes.

Consecutive No.	Station.	Latitude.	Longitude.	Mark.*
		°	°	
1	Abhona	20·5	73·9	●
2	Abu	24·6	72·7	⊡
3	Ahmedabad	23·0	72·6	⊡
4	Ahmednagar	19·1	74·8	⊹⊡
5	Ajmir	26·4	74·7	□
6	Akalkot	17·5	76·2	○
7	Akola	20·7	77·0	□
8	Akola	19·6	74·1	●
9	Alibág	18·6	72·9	●
10	Almel	17·1	76·3	●
11	Álta	16·7	74·5	●
12	Amalner	21·2	74·9	●
13	Amalsád	20·9	73·0	□
14	Ámbegaon	19·1	73·8	●
15	Ámbli	23·1	72·5	□
16	Ámod	22·0	72·9	●
17	Amraoti	20·9	77·8	□
18	Amroli	21·3	72·9	□
19	Ánand	22·6	73·0	⊡
20	Ándheri	19·1	72·9	□
21	Ankleswar	21·6	73·0	⊡
22	Ashta	17·0	74·5	●
23	Átgaon	19·5	73·3	□
24	Athni	16·7	75·1	●
25	Aurungabad	19·9	75·3	□
26	Bádámi	15·9	75·8	●
27	Badlápur	19·1	73·3	□
28	Badnera	20·8	77·8	□
29	Bágalkot	16·2	75·7	●
30	Bágewári	16·6	76·0	●
31	Baglon	20·8	75·7	●
32	Bágra	22·7	77·9	□
33	Baitul	21·9	78·0	□
34	Balari	25·3	68·2	●
35	Balwara	22·4	76·0	□
36	Bandora	19·1	72·9	⊡
37	Bankeri	22·7	78·6	□
38	Barajree	22·9	72·7	□
39	Barakdera	25·5	74·7	□
40	Bárámati	18·2	74·6	●
41	Bárdoli	21·1	73·1	●
42	Báriya	22·7	74·0	●
43	Baroda	22·3	73·2	⊹⊡
44	Bársi	18·2	75·7	●
45	Bársi Road	18·1	75·5	□
46	Barwai	22·3	76·1	□
47	Bassein	19·3	72·8	⊡
48	Bassim	20·1	77·2	□
49	Baura	16·5	73·9	●
50	Beaver	26·1	74·4	□
51	Beder	17·9	77·5	□
52	Belgaum	15·8	74·5	⊹⊡
53	Bhadgaon	20·6	75·2	●
54	Bhaluj	22·7	73·1	□
55	Bhawnagar	21·8	72·2	●
56	Bhilád	20·3	72·8	□
57	Bhilpank	23·3	75·2	□

* *Rainfall* stations are indicated by ●; stations whose *heights* are given by □; *wind* stations by ⊹; *temperature* stations by ○; rainfall, height, wind, and temperature stations are indicated by a combination mark, thus ⊹⊡; and other combinations of phenomena in a similar manner.

Consecutive No.	Station.	Latitude.	Longitude.	Mark.
		°	°	
58	Bhiwandi	19·3	72·9	●
59	Bhilwara	25·4	74·7	□
60	Bhondarwara	26·0	74·8	□
61	Bhudhargarh*	16·2	74·0	●
62	Bhuj	23·3	69·8	⊡
63	Bhusáwal	21·0	75·8	⊡
64	Bidi	15·6	74·7	●
65	Bijápur	16·8	75·8	⊡
66	Bilgi	16·4	75·6	●
67	Bilimora	20·8	73·0	□
68	Bir	22·0	76·5	□
69	Boisar	19·8	72·8	□
70	Bombay	18·9	72·8	⊡
71	Boondanwaree	24·8	67·7	□
72	Bori	20·9	79·1	□
73	Borsad	22·5	73·0	●
74	Borwali	19·2	72·9	□
75	Brahmunwara	19·3	74·0	●
76	Broach	21·7	73·0	⊡
77	Bulsar	20·6	72·9	⊡
78	Bundoory	21·0	70·3	□
79	Burhánpur	21·3	76·2	□
80	Burnagur	23·0	75·4	□
81	Campooly	18·8	73·4	□
82	Chálisgaon	20·5	75·0	⊡
83	Chamárgám	21·8	73·0	□
84	Chándni	21·4	76·4	□
85	Chándor	20·4	74·2	●
86	Chandúr	20·8	78·0	□
87	Charchan	17·9	75·3	●
88	Chárori	23·1	72·2	□
89	Chikhli	20·8	73·1	●
90	Chikori	16·4	74·6	●
91	Chikságar	16·4	77·4	□
92	Chinchwad	18·6	73·8	□
93	Chiplun	17·5	73·6	●
94	Chitapur	17·1	77·2	□
95	Chittor	24·9	74·7	□
96	Chopra	21·2	75·3	●
97	Coompta	14·4	74·5	●
98	Coorla	19·1	72·9	⊡
99	Dáhánu	20·0	72·7	⊡
100	Dahiwali	19·0	73·4	●
101	Dahiwari	17·8	74·5	●
102	Dákor	22·8	73·2	⊡
103	Daloda	23·9	75·2	□
104	Daman Road	20·4	72·9	□
105	Dambal	15·3	75·8	⊡
106	Dápoli	17·8	73·2	⊡
107	Dárbeji	24·8	67·6	⊡
108	Deesa	24·3	72·2	⊡
109	Dewar Hubli	15·3	75·0	●
110	Dhandhuka	22·3	72·0	●
111	Dharur	17·3	77·9	□
112	Dharwar	15·4	75·1	⊡
113	Dholka	22·7	72·5	●
114	Dhond	18·5	74·6	□
115	Dhorájee	21·7	70·6	□
116	Dhulia	20·9	74·8	⊡
117	Diksál	18·4	74·8	□
118	Dindori	20·3	73·7	●
119	Dodar	23·7	75·2	□
120	Dohad	22·8	74·3	●
121	Dongargaon	21·6	76·4	□
122	Dubhoe	22·2	73·5	□
123	Dudhni	17·4	76·4	□
124	Dungri	20·7	73·0	□
125	Edar	23·8	73·1	●
126	Erandol	20·8	75·3	●
127	Erinpura	25·1	73·2	□
128	Etola	22·1	73·2	□

* This place is supposed to be identical with the Bhyruoghur of the G. T. Survey map; and the position given is for the latter place.

Consecutive No.	Station.	Latitude.	Longitude.	Mark.
		°	°	
129	Fatehabad	23·1	75·8	□
130	Gadag	15·4	75·7	⊡
131	Gadarwára	22·9	78·9	□
132	Gangrar	25·0	74·6	□
133	Gholwad	20·1	72·7	□
134	Ghoti	19·8	73·6	□
135	Goa	15·5	74·0	⊕
136	Godhra	22·7	73·6	•
137	Gogo	21·7	72·3	⊕
138	Gokák	16·1	74·8	•
139	Guder	17·4	76·7	□
140	Guhágar	17·5	73·2	•
141	Guttal	14·8	75·7	•
142	Hála	25·8	68·5	•
143	Haliyál	15·3	74·8	•
144	Hálol	22·5	73·5	•
145	Hamirghar	25·2	74·6	□
146	Hángal	14·7	75·2	•
147	Hánsot	21·6	72·8	•
148	Harihar	14·5	75·9	○
149	Hessurur	15·2	76·0	□
150	Hingunghat	20·5	78·9	□
151	Hippargi	16·9	76·1	•
152	Hirekerur	14·4	75·4	•
153	Honáwar	14·3	74·5	•
154	Hubli	15·3	75·2	•
155	Hudgi	17·6	76·1	□
156	Hungund	16·0	76·1	•
157	Hushangabad	22·8	77·8	□
158	Hussain Sagur	17·3	78·4	□
159	Hyderabad	25·4	68·4	⊡
160	Hyderabad	17·3	78·5	□
161	Igatpuri	19·7	73·6	⊡
162	Illampalli	17·3	78·0	□
163	Illapur	17·2	77·5	□
164	Indápur	18·2	75·0	•
165	Indi	17·2	76·0	•
166	Indore	22·7	75·9	□
167	Itarsi	22·6	77·7	□
168	Jacobabad	28·3	68·5	⊕
169	Jakhwára	23·1	72·1	□
170	Jalalpur	20·9	72·9	•
171	Jalgaon	20·9	75·6	□
172	Jálna	19·8	75·9	⊡
173	Jambusar	22·1	72·8	•
174	Jámkhed	18·8	75·4	•
175	Jámner	20·7	75·8	•
176	Jasheepoora	21·4	70·5	□
177	Jerruck	25·0	68·3	•
178	Jeur	18·3	75·2	□
179	Jeypore	27·0	75·9	□
180	Jhálod	23·1	74·1	•
181	Jhimpir	25·0	68·1	□
182	Jowra	23·6	75·2	□
183	Jungsháhi	24·9	67·8	⊡
184	Junnar	19·2	74·0	•
185	Kaira	22·8	72·8	•
186	Kajgaon	20·6	75·1	□
187	Kaládgi	16·2	75·5	⊡
188	Kálol	22·6	73·5	•
189	Kalyán	19·2	73·1	⊡
190	Kankali	16·2	73·7	•
191	Kapadwanj	23·1	73·1	•
192	Karabgaon	17·5	76·2	□
193	Karád	17·3	74·2	•
194	Karajgi	14·9	75·5	•
195	Karanja	18·8	72·9	•
196	Karjat	18·9	73·4	⊡
197	Karjat	18·6	75·0	•
198	Karmala	18·4	75·2	•
199	Karnal	15·8	78·0	□
200	Karwan	22·1	73·3	□

Consecutive No.	Station.	Latitude.	Longitude.	Mark.
		°	°	
201	Karwar	14·8	74·2	⊡
202	Kására	19·6	73·5	□
203	Kávnai	19·8	73·7	•
204	Kedgaon	18·5	74·4	□
205	Kem	18·2	75·3	□
206	Keti Bander	24·1	67·5	•
207	Khálápur	18·8	73·3	•
208	Khánápur	17·3	74·7	•
209	Khánápur	15·6	74·5	•
210	Khandála	18·8	73·4	□
211	Khandála	18·1	74·1	•
212	Khandwa	21·8	76·4	□
213	Khangaum	20·7	76·6	□
214	Khardi	19·6	73·4	□
215	Kharepátan	16·6	73·7	•
216	Kharkála	18·8	73·6	⊡
217	Khed	18·9	73·9	•
218	Khed	17·7	73·4	•
219	Kherwári	20·1	73·8	□
220	Khipra	25·8	69·4	•
221	Kim	21·5	72·9	□
222	Kirkee	18·6	73·9	⊡
223	Kirkian	22·2	76·9	□
224	Kolhápur	16·7	74·3	⊡
225	Kopargaon	19·8	74·5	•
226	Koregaon	17·7	74·2	•
227	Kotri	25·3	68·3	⊡
228	Krishna	16·5	77·3	□
229	Kulbarga	17·4	76·9	□
230	Kurrachee	24·8	67·1	⊡
231	Kusmore	28·5	69·4	□
232	Lakhtar	22·8	71·8	□
233	Landi	24·9	67·2	•
234	Lánja	16·9	73·6	•
235	Lárkána	27·5	68·2	⊡
236	Lásalgaon	20·1	74·2	□
237	Lilápur	22·9	71·9	□
238	Lingampalli	17·3	78·2	□
239	Lohára	20·7	75·6	•
240	Lonauli	18·8	73·5	□
241	Lunáwára	23·1	73·7	•
242	Mádha	18·1	75·6	⊡
243	Mahableshwar	18·0	73·7	⊕
244	Mahád	18·1	73·5	•
245	Máheji	20·8	75·5	□
246	Máhim	19·7	72·7	•
247	Máhim	19·0	72·8	□
248	Mahudha	22·8	73·0	•
249	Málegaon	20·5	74·6	⊕
250	Malgund	17·2	73·3	•
251	Malirri	24·8	67·3	□
252	Malkápur	20·9	76·3	□
253	Málsirus	17·9	74·9	•
254	Málwan	16·0	73·5	•
255	Managoli	16·7	75·9	•
256	Mandangarh	17·7	73·3	•
257	Mándhardeo	18·0	73·8	⊕
258	Mandesor	24·0	75·2	□
259	Mandrup	17·5	75·8	•
260	Mándvi	21·3	73·3	•
261	Mángaon	18·3	73·3	•
262	Manmád	20·2	74·4	□
263	Másur	17·4	74·2	•
264	Mátar	22·7	72·7	•
265	Matheran	19·0	73·3	⊕
266	Meagam	22·0	73·1	□
267	Medha	17·8	73·9	•
268	Mehar	27·2	67·9	⊕
269	Mehidpur	23·5	75·7	⊕
270	Mehmadabad	22·8	72·8	⊡
271	Meting	25·1	68·2	⊡
272	Mhasáwad	20·8	75·5	□
273	Mhow	22·6	75·8	⊕
274	Mhow, near (highest point on railway line)	22·6	75·8	□
275	Mirpur Batoro	24·7	68·3	•
276	Misrekot	15·2	75·1	•

Consecutive No.	Station.	Latitude.	Longitude.	Mark.
		°	°	
277	Mitti - -	24·7	69·9	⊕
278	Mohol - -	17·8	75·7	⊡
279	Mokhára - -	19·9	73·3	•
280	Moolsi - -	18·5	73·5	•
281	Muddebihál -	16·4	76·2	•
282	Mundala - -	22·2	73·4	□
283	Murbád - -	19·2	73·4	•
284	Murtizapur -	20·7	77·3	□
285	Nadgund - -	15·7	75·4	•
286	Nagar Párkar -	24·4	70·8	•
287	Nagpur - -	21·1	79·2	□
288	Nalwár - -	17·0	77·1	□
289	Nándgaon - -	20·3	74·7	⊡
290	Nándur - -	19·9	73·8	□
291	Nándur - -	19·2	77·3	□
292	Nandura - -	20·8	76·5	□
293	Nandurbár - -	21·4	74·3	•
294	Nápád - -	22·7	73·0	•
295	Nargaon - -	20·8	76·1	□
296	Nariád - - -	22·7	73·0	⊡
297	Násik - -	20·0	73·8	⊡
298	Nasirabad - -	26·3	74·8	⊡
299	Nasirabad - -	20·9	75·7	⊡
300	Nausari - -	20·9	72·9	□
301	Nawágám - -	24·5	74·8	□
302	Nawalgund - -	15·5	75·4	•
303	Náydongri - -	20·3	74·9	□
304	Neral - -	19·0	73·3	□
305	Newása - -	19·6	75·0	•
306	Nimach - -	24·5	74·9	⊕
307	Nimbhera - -	24·6	74·7	□
308	Niphád - -	20·1	74·0	⊡
309	Olpád - - -	21·4	72·7	•
310	Oojein - -	23·2	75·9	□
311	Pábal - -	18·9	74·1	•
312	Páchháp ur - -	16·0	74·7	•
313	Páchora - -	20·7	75·4	⊡
314	Pálanpur - -	24·2	72·4	•
315	Pálej - -	21·9	73·0	□
316	Pálghar - -	19·7	72·8	□
317	Pánchgani - -	17·9	73·8	⊡
318	Pandharpur -	17·7	75·4	•
319	Panhála - -	16·8	74·2	•
320	Pánoli - -	21·6	73·0	□
321	Panwel - -	19·0	73·2	•
322	Parántij - -	23·4	72·9	•
323	Párdi - -	20·5	72·9	⊡
324	Párner - -	19·0	74·4	•
325	Pátan - -	17·4	74·0	•
326	Pátas - -	18·5	74·5	⊡
327	Patna (6 miles east of)	15·8	74·2	□
328	Pátri - -	23·1	71·9	□
329	Pattapur - -	17·4	78·2	□
330	Peint - -	20·4	73·4	•
331	Pen - -	18·7	73·1	•
332	Phaltan - -	18·0	74·5	⊡
333	Pimpalner - -	20·9	74·2	•
334	Pomalwári - -	18·3	75·0	□
335	Poona - -	18·5	73·9	⊡
336	Pulgaon - -	20·7	78·3	□
337	Purandhar - -	18·3	74·0	⊡
338	Ráhuri - -	19·5	74·7	•
339	Raichur - -	16·2	77·4	□
340	Rájápur - -	16·7	73·6	•
341	Rájkot - -	22·3	70·8	⊡
342	Ránder - -	21·3	72·8	•
343	Ránibennur - -	14·6	75·7	•
344	Rao - -	22·7	75·8	□
345	Ratnágiri - -	17·0	73·3	⊡
346	Rattihalli - -	14·4	75·6	•
347	Ráver - -	21·2	76·1	⊡
348	Ráygarh - -	18·3	73·4	•
349	Roha - - -	18·4	73·2	•

Consecutive No.	Station.	Latitude.	Longitude.	Mark.
		°	°	
350	Rohri - -	27·7	68·9	⊹
351	Ropera - -	26·9	76·0	□
352	Runija - -	23·2	75·2	□
353	Rupaili - -	25·7	74·7	□
354	Rutlam - -	23·4	75·1	□
355	Sabli-Road - -	23·0	71·9	□
356	Sachin - -	21·1	72·8	□
357	Sagar - - -	23·8	78·8	□
358	Ságtála - -	22·5	73·9	•
359	Saidápur - -	16·6	77·2	□
360	Sakrani - -	25·9	74·8	□
361	Samber, Salt Lake -	27·0	75·1	□
362	Sampgaon - -	15·8	74·8	•
363	Sánand - -	23·1	72·4	□
364	Sánand - -	23·0	72·4	•
365	Sanawad - -	22·2	76·2	□
366	Sangameshwar -	17·2	73·6	•
367	Sangamner - -	19·6	74·2	•
368	Sángola - -	17·4	75·2	•
369	Sánjan - -	20·2	72·8	□
370	Sánkhera - -	22·2	73·6	•
371	Saphála - -	19·6	72·9	□
372	Satara - -	17·7	74·1	⊡
373	Sauda - -	21·1	75·9	⊡
374	Saundatti - -	15·8	75·2	•
375	Sáwant-Wári -	15·9	73·9	•
376	Sawanur - -	15·0	75·4	•
377	Sawarde - -	17·4	73·6	•
378	Sawargaon - -	20·1	74·4	•
379	Sáyan - -	21·4	72·9	□
380	Secunderabad -	17·4	78·5	□
381	Sehor - -	23·2	77·1	□
382	Sehwan - -	26·4	67·9	⊡
383	Seram - -	17·2	77·4	□
384	Sháhábád - -	17·2	77·0	□
385	Sháháda - -	21·6	74·5	•
386	Sháhápur - -	19·5	73·3	⊡
387	Shegaon - -	20·8	76·7	□
388	Shegaon - -	19·3	75·3	•
389	Shiggaon - - -	15·0	75·3	•
390	Shikárpur - - -	28·0	68·7	⊡
391	Shirála - - -	17·0	74·1	•
392	Shirpur - -	21·3	75·0	•
393	Sholapur - -	17·7	76·0	⊡
394	Shrigonda - -	18·7	74·7	•
395	Siddápur -	14·3	74·9	•
396	Sindgi - -	16·9	76·2	•
397	Sindi - -	20·8	79·0	□
398	Sinnar - -	19·8	74·1	•
399	Sioni - - -	22·4	77·4	□
400	Sirsi - - -	14·6	74·8	•
401	Sirúr - -	18·8	74·4	⊡
402	Sohágpur - -	22·7	78·2	□
403	Sukkur - -	27·7	68·8	•
404	Sultánpur - -	21·7	74·7	•
405	Supa - - -	19·0	74·5	•
406	Supa - -	15·2	74·5	•
407	Surat - -	21·2	72·8	⊡
408	Talegaon - -	18·7	73·8	□
409	Taloda - -	21·6	74·3	•
410	Tando Aláhyar -	25·5	68·7	⊹
411	Tando Muhammad Khan - -	25·1	68·6	⊙
412	Tandur - -	17·3	77·7	□
413	Tanna - -	19·0	73·0	⊡
414	Tásgaon - -	17·0	74·6	•
415	Tatta - -	24·7	68·0	⊡
416	Thálner - -	21·3	75·0	•
417	Tháno Bulakhán -	25·4	67·9	•
418	Thárú Sháh - -	26·9	68·2	⊹
419	Thásra - -	22·9	73·2	•
420	Titwála - -	19·3	73·2	□
421	Tungár Hill -	19·4	73·1	⊹
422	Udepur - -	24·6	73·7	□
423	Umarkot - -	25·4	69·8	⊙
424	Umbargám - -	20·2	72·8	•

Consecutive No.	Station.	Latitude.	Longitude.	Mark.
		°	°	
425	Umreth - -	22·7	73·2	□
426	Uran - -	18·9	73·0	•
427	Uruli - - -	18·5	74·2	□
428	Veráwal - -	20·9	70·4	□
429	Vinchur - -	20·1	74·2	•
430	Vingorla - -	15·8	73·7	⊙
431	Viramgám - -	23·1	72·0	□
432	Virár - -	19·4	72·9	□
433	Virdel - -	21·3	74·8	•
434	Virpur - -	23·2	73·6	•
435	Vishálgarh - -	16·9	73·8	•
436	Wadhwán - -	22·7	71·7	⊡
437	Wadi - -	17·1	77·0	□
438	Wagotun - -	16·6	73·5	•
439	Wágra - -	21·9	72·8	•
440	Wai - -	18·0	74·0	•
441	Wálod - -	21·0	73·3	•
442	Wára - -	19·7	73·2	•
443	Warangaon - -	20·9	75·9	⊡
444	Wardha - -	20·7	78·6	□
445	Waruj - -	17·6	74·5	•
446	Wásad - -	22·5	73·2	□
447	Wásind - -	19·4	73·3	⊡
448	Yádágiri - -	16·8	77·2	□
449	Yellápur -	14·9	74·7	⊡
450	Yellápur, near (43 miles from Karwar)	14·9	74·7	□
451	Yeola - -	20·1	74·4	•

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